1

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EVALUATION OF THE BIRDSTRIKE THREAT TO THE F-15 PRESENT FLEET, RAPID DEPLOYMENT FORCE, AND DUAL ROLE FIGHTER TRANSPARENCIES

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This technical report has been reviewed and is approved for publication.

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The information contained in this report is developed from analytical and empirical techniques used to establish statistical models for evaluating the birdstrike threat to the F-15 aircraft transparencies. Consideration is given to two areas: (1) the operational impact rate for specific aircraft usage profiles, and (2) the probability of a random birdstrike which could result in penetration of the aircraft cockpit.

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FOREWARD

This report covers work performed by the author during his support of the F-15 Systems Program Office (SPO) at Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, OH. The period covered was January 1983 through July 1983. The purpose of the effort was to assess the F-15 Present Fleet, Rapid Deployment Force, and Dual Role Fighter windshield and canopy bird impact resistance capability.

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TABLE OF CONTENTS

A-1

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

Collisions between birds and aircraft have become one of the major flight safety problems of the jet age. The most critical need for bird impact resistance design improvement is in military aircraft. Many high speed aircraft in USAF inventory were not designed to meet today's bird impact requirements because the threat in terms of lost aircraft and aircrews was not fully appreciated at the design stage.

A comprehensive review of analytically and empirically developed predictive techniques for bird impact structural performance has not revealed a simple approach, that is, simple to use on short notice or that requires a minimum of input information, nor one that is universally available and universally accepted.

The statistical model for evaluating the birdstrike threat to aircraft transparencies is based on two components: (1) the operational impact rate for a specific usage profile; and (2) the probability that a random birdstrike will occur with sufficient kinetic energy to cause penetration into the aircraft cockpit. This model is based on methods formulated by Dr John Halpin in evaluating the birdstrike threat on the F-16 canopy and Dr Allan Berens' model in evaluating the T-38 crew enclosure system.

This statistical simulation combines the velocity distribution of the aircraft, the bird weight distribution, and the capability of the crew enclosure expressed in terms of kinetic energy. The above distributions were developed for the F-15 Present Fleet, Rapid Deployment Force and Dual Role Fighter. Then, an assessment was made to determine the number of bird penetrations that can be expected on the windshield and canopy over a realistic usage profile.

The approach presented in this report is quite simple to use, since computer programs were generated to reduce the tedious calculations to a minimum. The use of these methods will allow an engineer to make a fairly quick assessment in regard to the adequacy/inadequacy of a crew enclosure system bird resistance capability.

OPERATIONAL IMPACT RATE

As an aircraft flies through a bird threat environment, usually 0 - 5000 ft AGL, it sweeps out a volume which is a function of the crew enclosure frontal projected area, time and aircraft velocity in the bird threat environment. Therefore, it can be concluded that:

$$\text{VOLUME} = \text{VELOCITY} \times \text{AREA} \times \text{TIME} \quad (1)$$

This volume per unit time that is swept out is projected through the bird threat environment with a given bird density ρ. The product of the volume per unit time and bird density is the Operational Impact Rate (OIR) on the crew enclosure (Figure 1)

$$\text{OIR} = \bar{V} \times A \times Ts \times \rho \quad (2)$$

where

OIR = operational impact rate
$\bar{V}$ = aircraft mean true velocity
A = windshield or canopy frontal projected area
Ts = $\dfrac{\text{time in bird threat environment}}{\text{total flight time}}$

ρ = bird density in environment

A ratio can be developed between any two aircraft if one knows the operational impact rate of one of the aircraft:

$$\text{OIR}_2 = \text{OIR}_1 \times \frac{\bar{V}_2 \times A_2 \times Ts_2 \times \rho_2}{\bar{V}_1 \times A_1 \times Ts_1 \times \rho_1} \quad (3)$$

The mean velocities, subsystem frontal areas and proportions of time are directly measurable and can be calculated with a moderate amount of effort. However, bird density is not directly measurable, and if one tries to determine the bird density analytically, such a density may be biased by huge populations of small birds such as robins and blackbirds, which have frequently impacted aircraft. Another approach would be to assume that the two aircraft fly in approximately the same environments and therefore experience the same bird densities. This would cancel out the two densities and leave the equation as:

$$\text{OIR}_2 = \text{OIR}_1 \times \frac{\bar{V}_2 \times A_2 \times Ts_2}{\bar{V}_1 \times A_1 \times Ts_1} \quad (4)$$

Caution needs to be used in this type of approximation, (assuming equal bird densities) since evaluation of existing bird impact data for the F-4 and F-111 (obtained from the Bird Aircraft Strike Hazard (BASH) TEAM at Tyndall AFB) revealed a significant difference in the predicted operational impact rates.

OPERATIONAL IMPACT RATE = (PROJECTED AREA) X (VELOCITY) X (TIME) X (BIRD DENSITY)

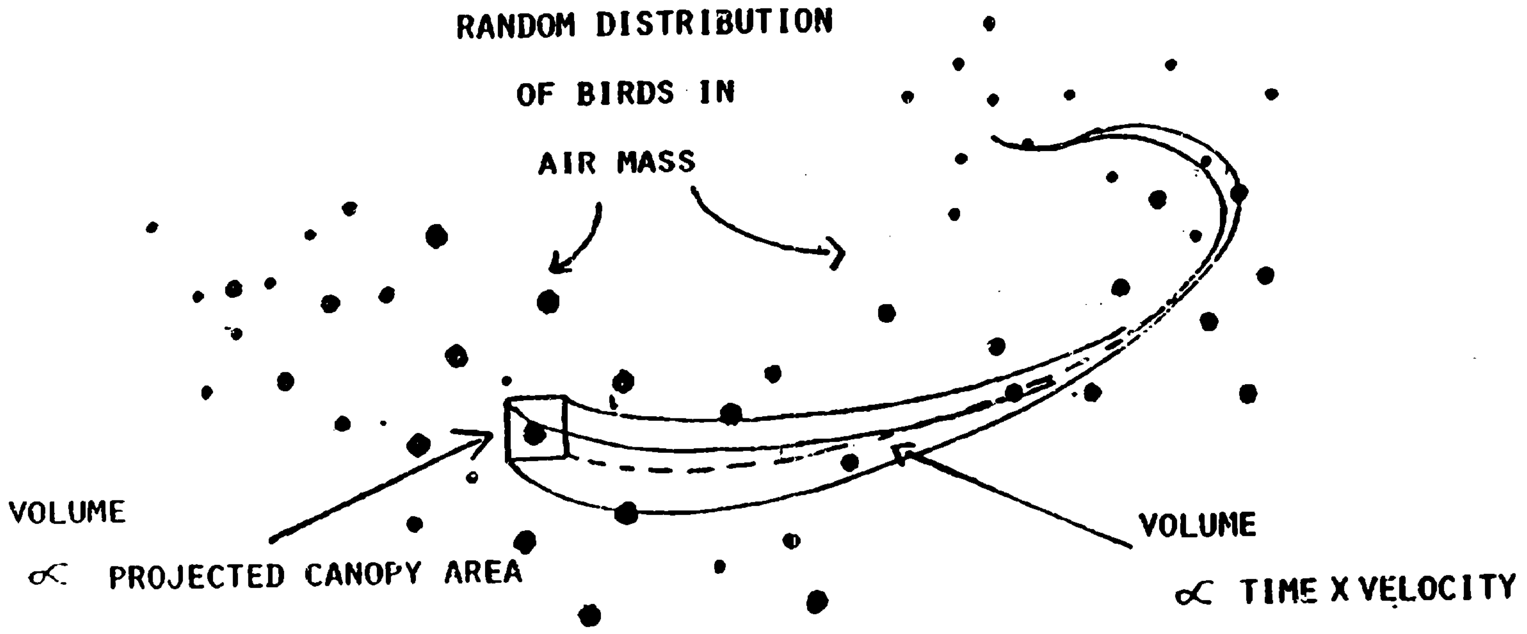


FIG. 1 VOLUME SWEPT OUT BY AIRCRAFT IN BIRD ENVIRONMENT

Using the known OIR for the F-4, the F-111 predicted OIR was high by approximately a factor of two. Reversing the simulation showed the F-4 predicted OIR to be low by approximately a factor of two. A realistic consideration of this disparity is quite logical, since each aircraft does not fly at the same exact locations of the world and therefore does not encounter the same bird densities. Any extrapolation between any two unique aircraft that are not based at the same locations will exhibit this phenomenon, and some sort of correction factor needs to be used.

In the analysis of the F-15 present fleet, Rapid Deployment Force (RPD) and Dual Role Fighter (DRF), the bird densities were assumed constant since the RPD and DRF are expected to fly at the same bases from which the historical OIR was obtained.

FOR EXAMPLE: Windshield, Europe

$$OIR_{\substack{DRF\\Europe}} = OIR_{\substack{Present\\Fleet\\Europe}} \times \frac{\overline{V}_{DRF} \times Ts_{\substack{DRF\\Europe}} \times A_{DRF}}{\overline{V}_{\substack{Present\\Fleet}} \times Ts_{\substack{Present\\Fleet\\Europe}} \times A_{\substack{Present\\Fleet}}} \times \cancelto{1}{\frac{\rho_{\substack{DRF\\Europe}}}{\rho_{\substack{Present\\Fleet\\Europe}}}} \qquad (5)$$

Table 1 summarizes the historical operational impact rates for the present fleet based on the time frame of April 1976 - 1 May 1983. Table 2 summarizes the flight hours flown by each F-15 using command. Conus flight hours is a summation of TAC, Systems, and Logistic Commands usage. Alaskan Command and PACAF were not analyzed since to date their operational impact rate on the windshield and canopy is zero, and their hourly usage was minimal compared to the usage in Conus and Europe (USAFE). Finally, Eqn. (5) is used with the appropriate inputs from Table 3 to determine the predicted OIR for the RPD and DRF for each of the following:

(A) Conus and Europe

(B) Air to Air and Air to Ground missions

(C) Windshield and Canopy

(D) T_s variable from 0 - .9

Example Application of Eqn (5)

For F-15 DRF, Windshield, Europe, A/G Mission Assume DRF t_s = .7

$$OIR_{\substack{DRF\\EUROPE/10^6\ HRS}} = 21.97/10^6\ HRS \times \frac{445.91}{279.24} \times \frac{.70}{.2307} \times \frac{602.5}{602.5} \times 1$$

$$OIR_{\substack{DRF\\EUROPE/10^6\ HRS}} = 106.45\ IMPACTS$$

TIME FRAME = APRIL 1976 - 1 MAY 1983

CONUS

HOURS FLOWN = 473,008

Windshield	OIR	= 14.00	
	OIR/10^6 Hrs	= 29.60	
			Ts = .1198
Canopy	OIR	= 2.00	
	OIR/10^6 Hrs	= 4.23	

EUROPE

HOURS FLOWN = 136,576

Windshield	OIR	= 3.00	
	OIR/10^6 Hrs	= 21.97	
			Ts = .2307
Canopy	OIR	= 7.00	
	OIR/10^6 Hrs	= 51.25	

BIRD IMPACTS OBTAINED FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES FOR ABOVE TIME FRAME

TABLE 1 F-15 PRESENT FLEET HISTORICAL OPERATIONAL IMPACT RATES

YEAR	COMPOSITE ALL A.F.	ALASKAN COMMAND	USAFE	LOG COMMAND	PACAF	SYSTEMS COMMAND	TAC
Apr 1976	1,211	0	0	0	0	61	1,150
May 1976	1,124	0	0	0	0	37	1,087
Jun 1976	1,394	0	0	0	0	124	1,270
Jul 1976	1,576	0	0	0	0	97	1,479
Aug 1976	1,787	0	0	0	0	104	1,683
Sep 1976	1,746	0	0	0	0	84	1,662
Oct 1976	1,936	0	0	0	0	94	1,842
Nov 1976	2,243	0	0	3	0	102	2,138
Dec 1976	2,307	0	0	0	0	61	2,246
1977	42,369	0	8,588	10	0	959	32,812
1978	69,023	0	17,916	48	0	1,126	49,933
1979	96,959	0	22,925	191	1,817	1,644	70,382
1980	109,309	0	23,078	406	15,181	1,895	68,749
1981	132,291	0	26,153	387	20,532	1,554	83,665
1982	153,369	2,762	28,471	216	19,923	2,314	99,683
Jan 1983	13,663	664	2,004	12	1,947	206	8,830
Feb 1983	13,258	432	2,223	21	1,973	205	8,404
Mar 1983	14,792	758	2,718	17	2,209	181	8,909
Apr 1983	15,017	667	2,500	18	2,206	213	9,411
Total	675,374	5,283	136,576	1,329	65,788	11,061	455,335

Information obtained from Mr Vincent Clark, AV 876-4948, Norton AFB

TABLE 2 F-15 PRESENT FLEET TOTAL USAGE (FLIGHT HOURS)

F-15 PRESENT FLEET

$AREA_{WINDSHIELD}$	= 602.5 IN^2
$AREA_{CANOPY}$	= 280.0 IN^2
$\overline{V}_{AIR\ TO\ AIR}$	= 279.24 Knots (CONUS & Europe)
t_s CONUS	= .1198 based on historical data
t_s EUROPE	= .2307 based on historical data

F-15 RAPID DEPLOYMENT FORCE (RPD)

$AREA_{WINDSHIELD}$	= 602.5 IN^2
$AREA_{CANOPY}$	= 280.0 IN^2
$\overline{V}_{AIR\ TO\ AIR}$	= 279.24 Knots (CONUS & Europe)
$\overline{V}_{AIR\ TO\ GROUND}$	= 427.90 Knots (CONUS & Europe)
t_s CONUS AND EUROPE	= Varies 0 - .9

F-15 DUAL ROLE FIGHTER (DRF)

$AREA_{WINDSHIELD}$	= 602.5 IN^2
$AREA_{CANOPY}$	= 474.5 IN^2
$\overline{V}_{AIR\ TO\ AIR}$	= 279.24 Knots (CONUS & Europe)
$\overline{V}_{AIR\ TO\ GROUND}$	= 445.91 Knots (CONUS & Europe)
t_s CONUS AND EUROPE	= Varies 0 - .9

TABLE 3 INPUT VARIABLES FOR EQN (5) OIR EXTRAPOLATION

Evaluation of Table 1 reveals a disparity for the Canopy and Windshield OIRs between Conus and Europe. Since the canopy has a lower projected frontal area from the windshield, it would be expected that the OIR on the canopy in Europe would be lower than the windshield OIR, however, this is not the case. Table 4.0-4.5 summarizes the bird impacts for the F-15, F-4 and F-111 by each theatre Conus/Europe and each component windshield/canopy. For Europe, from Table 4.1, 4.3, 4.5 the results are as follows:

	F-15	F-4	F-111
Windshield	3	38	20
Canopy	7	60	15

A possible explanation of this disparity is that a pressure wave is created by the aircraft radome in flight, with a component in the vertical direction strong enough to displace an oncoming bird over the windshield arch and hit the canopy. The pressure force would not be strong enough to displace a 4 lb bird, but it may be sufficient to displace a .1 - .3 lb bird. From Figure 5 (page 37) and 6 (page 51) bird weight distributions, the bird weight range 0 - .3 lbs, represents 35% of the bird population in Conus and 58% in Europe.

The above theory holds a great deal of logical sense, but it is only a crude rationalization of the results and it fails for the F-111. An in-depth analysis is necessary to verify this phenomenon with special consideration in the area of aerodynamic effects over the radome of each of the above aircraft, as well as geometrical similarity. For example, the F-15 and F-4 have basically geometrically similar windshields and canopies but the F-111 does not. It is felt that for the F-111 canopy the pressure wave effects are considerably different than the F-15 and F-4, since the F-111 is a side-by-side seating aircraft. Based on the above the theory would hold in Europe for the F-4 and F-15, but not for the F-111.

F-15 CONUS

ON CANOPY		ON WINDSHIELD	
STRIKE DATE	BASE	STRIKE DATE	BASE
78/04	Langley	78/09	Unknown
80/02	Langley	79/01	Robins
		79/08	Holloman
		79/12	Holloman
		80/02	George
		80/07	Langley
		81/07	Langley
		81/07	Langley
		81/11	Langley
		82/05	Langley
		82/07	Langley
		83/03	Holloman
		83/04	Luke
		83/05	Luke

Time Frame = April 1976-May 1983
Hours Flown = 473,008
Total = 2 on Canopy
14 on Windshield

Data from BASH team computer files, Tyndall AFB

TABLE 4.0 BIRD STRIKES ON CANOPY AND WINDSHIELD

F-15 EUROPE

ON CANOPY		ON WINDSHIELD	
STRIKE DATE	BASE	STRIKE DATE	BASE
78/06	Bitburg	78/07	Bitburg
79/09	Alconbury	81/05	Camp New Amsterdam
80/04	Camp New Amsterdam	81/07	Camp New Amsterdam
80/08	Camp New Amsterdam		
82/08	Spangdahlem		
82/08	Bitburg		
81/09	Camp New Amsterdam		

Time Frame = April 1976-May 1983
Hours Flown = 136,576
Total = 7 on Canopy
3 on Windshield

Data from BASH team computer files, Tyndall AFB

TABLE 4.1 BIRD STRIKES ON CANOPY AND WINDSHIELD

F-111 CONUS

ON CANOPY		ON WINDSHIELD	
STRIKE DATE	BASE	STRIKE DATA	BASE
75/07	Cannon	75/04	Nellis
79/09	Nellis	75/04	Cannon
75/10	Mt Home	76/06	Mt Home
76/08	Mt Home	78/02	Cannon
78/06	Mt Home	78/07	Unknown
78/06	Unknown	78/09	Unknown
78/10	Unknown	79/08	Unknown
78/10	Unknown	79/08	Unknown
78/10	Unknown	79/08	Unknown
79/04	Cannon	79/08	Unknown
79/07	Unknown	79/10	Unknown
79/10	Unknown	79/10	Unknown
79/11	Unknown	79/11	Unknown
79/12	Unknown	82/06	Mt Home
		82/09	Mt Home
		82/09	Mt Home

Time Frame = Jan 1975-Nov 1982
Hours Flown = Unknown
Total = 14 on Canopy
16 on Windshield

Data from BASH team computer files, Tyndall AFB

TABLE 4.2 BIRD STRIKES ON CANOPY AND WINDSHIELD

F-111 EUROPE

ON CANOPY		ON WINDSHIELD	
STRIKE DATE	BASE	STRIKE DATE	BASE
78/07	Unknown	75/11	Upper Heyford
78/09	Unknown	77/10	Upper Heyford
79/08	Unknown	78/08	Lakenheath
79/10	Unknown	78/08	Upper Heyford
80/07	Upper Heyford	78/09	Lakenheath
80/09	Upper Heyford	78/09	Unknown
81/10	Lakenheath	78/09	Unknown
82/04	Incirlik	78/10	Unknown
82/04	Incirlik	79/06	Unknown
82/11	Incirlik	80/10	Lakenheath
82/09	Upper Heyford	80/10	Upper Heyford
82/10	Upper Heyford	80/12	Upper Heyford
82/10	Upper Heyford	81/01	Upper Heyford
82/10	Upper Heyford	81/02	Upper Heyford
82/11	Upper Heyford	81/03	Incirlik
		81/06	Lakenheath
		81/09	Upper Heyford
		81/10	Unknown
		82/06	Lakenheath
		82/07	Upper Heyford

Time Frame = Jan 1975-Nov 1982
Hours Flown = Unknown
Total = 15 on Canopy
20 on Windshield

Data from BASH team computer files, Tyndall AFB

TABLE 4.3 BIRD STRIKES ON CANOPY AND WINDSHIELD

F-4 CONUS

ON CANOPY

STRIKE DATE	BASE
77/01	Boise (Gowen Fld) ID
78/04	Lincoln MAP NE
78/05	Unknown
79/03	Unknown
79/04	Unknown
79/04	Moody
79/04	Unknown
79/04	Unknown
79/04	Unknown
79/05	Moody
79/06	Unknown
79/07	Unknown
79/07	Unknown
79/09	Unknown
79/12	Unknown
80/01	Unknown
80/10	Duluth IAP MN
81/09	MacDill
81/01	Lincoln MAP NE
82/07	George
82/05	Shaw
82/06	Birmingham Muni
82/06	Hulman Field IN
82/11	Standiford Field KY
82/10	George

ON WINDSHIELD

STRIKE DATE	BASE
75/08	Holloman
77/01	Bergstrom
77/03	Shaw
77/06	Shaw
77/07	Birmingham Muni
78/02	Shaw
78/04	Seymour Johnson
78/05	Unknown
78/05	Unknown
78/06	George
78/07	Duluth IAP MN
78/08	Moody
78/08	Unknown
78/09	Unknown
78/10	Unknown
78/11	Unknown
78/11	Unknown
78/11	Moody
78/11	Homestead
79/03	George
79/05	Homestead
79/06	Unknown
79/07	Unknown
79/09	Luke
79/09	Unknown
79/10	Duluth IAP MN
79/10	Key Field MS
79/10	Unknown
79/11	Homestead
79/11	Shaw
79/12	Moody
80/03	Homestead
80/04	Bergstrom
80/07	Duluth IAP MN
80/09	George
80/11	Seymour Johnson
80/12	Seymour Johnson
81/05	VDLM
81/06	MacDill
81/07	Bergstrom
81/09	George
81/10	Kelly
82/06	Seymour Johnson
82/08	Duluth IAP MN
82/10	Edwards
82/11	Seymour Johnson
82/10	Seymour Johnson
82/11	Seymour Johnson

Time Frame = Jan 1975--Jul 1982
Hours Flown = Unknown
Total = 25 on Canopy
48 on Windshield

Data from BASH team computer files, Tyndall AFB

TABLE 4.4 BIRD STRIKES ON CANOPY AND WINDSHIELD

F-4 EUROPE

ON CANOPY

STRIKE DATE	BASE
75/03	Bitburg
76/04	Alconbury
78/03	Bitburg
78/07	Aviano
78/08	Torrejon
78/09	Unknown
78/09	Unknown
78/10	Unknown
78/10	Unknown
78/10	Unknown
78/12	Zweibrucken
79/01	Hahn
79/03	Unknown
79/06	Unknown
79/06	Spangdahlem
79/07	Unknown
79/09	Unknown
80/01	Unknown
80/02	Unknown
80/03	Unknown
80/05	Torrejon
80/07	Zweibrucken
80/07	Zweibrucken
80/08	Zaragoza
80/09	Incirlik
80/09	Ramstein
80/09	Zaragoza
80/09	Hahn
80/09	Hahn
80/09	Zweibrucken
80/09	Ramstein
80/10	Zweibrucken
80/10	Incirlik
80/10	Zaragoza
80/10	Zweibrucken
80/11	Ramstein
81/03	Incirlik
81/03	Incirlik
81/03	Incirlik
81/03	Ramstein
81/04	Incirlik
81/05	Incirlik
81/05	Hahn
81/07	Spangdahlem

ON WINDSHIELD

STRIKE DATE	BASE
75/09	Torrejon
78/02	Bentwaters
78/03	Bentwaters
78/06	Unknown
78/07	Hahn
78/07	Unknown
78/08	Unknown
78/09	Hahn
78/09	Unknown
78/09	Unknown
79/06	Unknown
79/06	Unknown
79/06	Unknown
79/07	Unknown
79/10	Hahn
80/07	Torrejon
80/08	Torrejon
80/08	Spangdahlem
80/10	Incirlik
80/11	Incirlik
81/03	Alconbury
81/03	Ramstein
81/05	Spangdahlem
81/06	Ramstein
81/06	Incirlik
81/07	Spangdahlem
81/07	Spangdahlem
81/07	Hahn
81/09	Torrejon
81/09	Incirlik
81/10	Zweibrucken
82/09	Ramstein
82/07	Zweibrucken
82/09	Zweibrucken
82/07	Torrejon
82/08	Torrejon
82/10	Torrejon

TABLE 4.5 BIRD STRIKES ON CANOPY AND WINDSHIELD

TABLE 4.5 F-4 EUROPE (Cont'd)

81/08	Torrejon
81/08	Alconbury
81/09	Spangdahlem
81/10	Incirlik
82/04	Incirlik
82/05	Zaragoza
82/05	Incirlik
82/05	Spangdahlem
82/06	Incirlik
82/06	Incirlik
82/06	Incirlik
82/09	Ramstein
82/07	Zweibrucken
82/07	Torrejon
82/07	Torrejon
82/08	Torrejon

Time Frame = Jan 1975-Jul 1982
Hours Flown = Unknown
Total = 60 on Canopy
38 on Windshield

Data from BASH team computer files, Tyndall AFB

Cumulative Probability Distributions

Additional inputs into the model include velocity, bird weight and crew enclosure strength cumulative distributions.

This model assumes that the velocity and bird weight distributions for the majority of the data can be modeled by a Weibull cumulative probability distribution.

The functional form of the cumulative Weibull distribution is given by:

$$F(V) = 1 - \exp\left[-\left(\frac{V-\gamma}{\beta-\gamma}\right)^{\alpha}\right] \tag{6}$$

Where:

$F(V)$ = cumulative velocity probability distribution

V = velocity

β = characteristic paramter, represents the 63 percentile point of the population sample

α = shape parameter

γ = minimum life parameter, in this analysis it is used only as a correction factor for the Weibull distribution

If portions of the data population do not fit a Weibull distribution, an approximation can be used by the following equation

$$F(V)_{Total} = F(V)_1 + F(V)_2 + \ldots F(V)_N \tag{7}$$

Equation 7 sums each cumulative distribution to get a total of 1. In this report, $F(V)_{Total}$ represents a cumulative probability distribution function which is a mixture of Weibull distributions and distributions that are defined by sixth or first order equations, depending on which data population is being analyzed.

The mean values may be obtained by taking the first derivative of each individual cummulative distribution, and applying the following formula

$$\overline{V}_1 = \int_A^B V\, f(V)_1\, dV \tag{8}$$

Where:

V = velocity

$f(V)$ = first derivative of $F(V)_1$ probability distribution

and

$$\overline{V}_{Total} = \overline{V}_1 + \overline{V}_2 + \overline{V}_3 + \ldots \quad (9)$$

$$\overline{V}_{Total} = \int_A^B Vf(V)_1\, dV + \int_B^C Vf(V)_2\, dV + \int_C^D Vf(V)_3\, dV + \ldots \quad (10)$$

Before a cumulative distribution can be assigned to a given set of data, it is necessary to reduce the data in a statistical manner. This can be accomplished by the following eqn.

$$\text{RELATIVE FREQUENCY} = \frac{f}{N} \quad (11)$$

where

f = frequency of occurrence

N = total number of occurrences

Eqn. 11 suggests that one can associate with a given event a number, say p, that is equal or approximately equal to that number about which the relative frequency seems to stabilize. The number p, associated with a given event is usually called a probability. Therefore

$$p = \text{PROBABILITY} = \text{RELATIVE FREQUENCY} = \frac{f}{N} \quad (12)$$

Once a given set of data is reduced to a probability form, it is arranged in increasing order to obtain a cumulative probability distribution. To this data, a known cumulative distribution function is fitted. This is done since the statistically reduced data sample contains some level of inaccuracy. The level of inaccuracy is a function of the source and the amount of data. For example, structural recorder data is more realistic and accurate in analyzing the F-15 Air to Air mission than obtaining information from a structural loads report.

A theoretical cumulative distribution such as the Weibull, Gama, Beta or dozens of others, which can be obtained from textbooks are exact, meaning they satisfy all axioms of probability. If a set of data fits any theoretical distribution exactly, the error in that data sample is zero. This occurrence is quite remote due to the inaccuracy in data measuring equipment. Therefore, the data is fitted with a known cumulative distribution, because such a distribution is more exact and represents actual aircraft usage more realistically for a particular mission profile.

This analysis uses primarily the Weibull cumulative probability distribution since this distribution was used exclusively by Dr Halpin and Dr Berens in their work in evaluating the F-16 and T-38 crew enclosure bird impact resistance capabilities. However, one should note that other known cumulative probability distributions could have been used and possibly provided a better fit to any one of the data samples in this report.

VELOCITY DISTRIBUTION FOR F-15 PRESENT FLEET

For the present fleet air to air mission, the velocity distribution was derived from structural recorder data from Kadena, Holloman, and Bitburg for a total of 347.5 flight hours. This data was obtained from McDonnell Douglas and reduced for an altitude range of 0 - 5000 ft AGL. Table 5.0 summarizes the present usage of the F-15 fleet.

Eqn 12 was then used to get the initial probabilities in the altitude range 0 - 5000 ft (Third Column, Table 4.1)

Where

f = # seconds for specific airspeed range

N = total seconds (490,981.8)

From this data, a cumulative probability was obtained (Fourth Column, Table 5.1). This data was then plotted on linear graph paper and fitted with a Weibull cumulative probability distribution.

KADENA + HOLLOMAN + BITBURG CUM

BASED ON 347.5 FLIGHT HOURS

TOTAL USAGE

SECONDS PER 1000 FLIGHT HOURS

TRUE AIRSPEED (KNOTS)	ALTITUDE - FEET: 0 TO 2500	2500 TO 5000	5000 TO 7500	7500 TO 10000	10000 TO 15000	15000 TO 20000	20000 TO 25000	25000 TO 30000	30000 TO 35000	35000 TO 40000	40000 TO 50000	50000 TO 60000	GT 60000	SECONDS
0.0 TO 30.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30. TO 60.	0.0	0.0	0.0	0.0	0.0	23.0	679.1	5.8	23.0	0.0	0.0	0.0	0.0	730.9
60. TO 90.	0.0	2.9	0.0	0.0	28.8	120.9	112.2	46.0	17.3	0.0	0.0	0.0	0.0	328.0
90. TO 120.	14.4	40.3	0.0	0.0	83.4	97.8	95.0	77.7	25.9	8.6	0.0	0.0	0.0	443.1
120. TO 150.	10.9	28.8	0.0	60.4	198.6	322.3	161.1	74.8	25.9	31.7	0.0	0.0	0.0	952.5
150. TO 180.	32289.4	19904.2	6017.0	187.0	984.1	1433.0	402.9	293.5	89.2	46.0	0.0	0.0	0.0	61646.5
180. TO 210.	30539.8	23881.1	14333.2	876.2	1928.0	2385.5	1392.8	601.4	164.0	40.3	0.0	0.0	0.0	75942.3
210. TO 240.	25725.6	29135.5	16828.1	1574.0	4103.4	3907.8	2811.4	909.3	446.0	63.3	0.0	0.0	0.0	85504.5
240. TO 270.	17541.7	34436.0	25518.4	4437.2	5758.0	4563.8	2929.4	1624.4	1568.3	123.7	7968.0	0.0	0.0	106669.1
270. TO 300.	13715.1	27847.8	35918.0	12071.4	18625.1	9173.7	4727.9	3615.7	1332.3	149.6	5625.7	0.0	0.0	136800.3
300. TO 330.	19757.5	36933.8	38061.8	19996.3	34910.8	26701.1	12411.0	8641.4	2592.7	748.2	17.3	0.0	0.0	200771.8
330. TO 360.	26154.6	39618.6	43903.3	33765.6	50098.7	30807.4	20318.6	12914.6	4808.4	1453.5	77.7	0.0	0.0	263960.7
360. TO 390.	13657.0	23224.0	32761.4	22082.6	44760.8	44444.3	17535.9	12025.4	6871.7	1746.7	270.5	0.0	0.0	221470.3
390. TO 420.	22111.3	19679.8	38246.0	34482.1	59114.2	75548.1	48271.5	27319.8	12877.2	4512.0	466.2	0.0	0.0	342628.0
420. TO 450.	7142.2	6244.3	22609.2	25366.8	55865.4	86969.2	77081.8	63652.1	19323.0	8560.8	1994.2	0.0	0.0	376810.8
450. TO 480.	1881.9	4379.7	11326.2	13634.0	35656.1	85616.7	101253.5	112568.2	34876.3	29365.7	10750.6	0.0	0.0	441309.0
480. TO 510.	739.5	1945.2	5447.5	6842.9	21423.6	53865.2	79217.0	65770.0	58907.0	54556.1	42870.2	0.0	0.0	391544.1
510. TO 540.	880.5	1801.4	5004.1	4420.0	22462.4	59494.0	72848.9	74394.1	96301.2	89582.0	33250.5	97.8	0.0	460537.0
540. TO 570.	1404.3	1597.1	3723.6	3654.5	20192.0	41339.4	52941.8	62403.3	50622.4	20615.0	4129.3	201.4	0.0	262824.0
570. TO 600.	509.3	1096.4	3015.7	3102.0	15864.1	27362.9	24635.0	18102.9	9055.9	5199.8	1700.7	448.9	0.0	110090.6
600. TO 630.	178.5	869.0	1424.4	2555.3	6848.6	5501.9	3694.8	4943.7	3907.8	768.3	483.4	175.5	0.0	31351.3
630. TO 660.	230.2	546.7	716.5	906.4	2610.0	4016.2	4235.8	1864.7	1004.3	1223.0	299.3	115.1	0.0	17838.1
660. TO 690.	63.3	164.0	155.4	374.1	1030.2	647.5	518.0	751.0	310.8	307.9	155.4	51.8	0.0	4529.3
690. TO 720.	0.0	112.2	138.1	115.1	374.1	201.4	152.5	204.9	238.8	264.7	164.0	221.6	0.0	2267.5
720. TO 750.	0.0	0.0	2.9	11.5	66.2	66.2	37.4	247.5	149.6	207.2	238.8	109.3	0.0	1136.9
750. TO 780.	0.0	0.0	5.8	25.9	17.3	34.5	40.3	120.9	184.2	218.7	250.3	83.4	0.0	981.3
780. TO 810.	0.0	0.0	0.0	0.0	34.5	69.1	20.1	0.0	40.3	83.4	175.5	0.0	0.0	423.0
810. TO 840.	0.0	0.0	0.0	0.0	0.0	5.8	2.9	0.0	0.0	2.9	77.7	0.0	0.0	89.2
840. TO 870.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7	0.0	0.0	31.7
870. TO 900.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.2	0.0	0.0	43.2
900. TO 930.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.0	0.0	0.0	46.0
930. TO 960.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.2	0.0	0.0	43.2
960. TO 990.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7	0.0	0.0	31.7
GT 990.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	169.8	54.7	0.0	0.0	224.5
SECONDS	215623.0	275358.8	305176.3	192343.4	404038.5	564748.7	530528.4	473653.0	305760.4	220048.8	111215.7	1505.0	0.0	

DATA OBTAINED FROM MCDONNELL DOUGLAS

TABLE 5.0 F-15 PRESENT FLEET USAGE

DATA FROM KADENA, HOLLOMAN AND BITBURG

TRUE AIRSPEED (KNOTS)	SECONDS	PROB = $\frac{\text{SECONDS}}{\text{TOTAL SECONDS}}$	CUM PROB
60-90	2.9	.0000	.0000
90-120	54.7	.0001	.0001
120-150	77.7	.0002	.0003
150-180	52193.6	.1063	.1066
180-210	54420.9	.1108	.2174
210-240	54861.1	.1117	.3291
240-270	51977.7	.1059	.4350
270-300	42360.9	.0863	.5213
300-330	56691.3	.1155	.6368
330-360	65813.2	.1340	.7708
360-390	36951.0	.0753	.8461
390-420	41791.1	.0851	.9312
420-450	15386.5	.0313	.9625
450-480	6261.6	.0128	.9753
480-510	2684.7	.0055	.9808
510-540	2681.9	.0055	.9863
540-570	3001.4	.0061	.9924
570-600	1605.7	.0033	.9957
600-630	1047.4	.0021	.9978
630-660	776.9	.0016	.9994
660-690	227.3	.0005	.9999
690-720	112.2	.0002	1.0000
TOTALS	490,981.0	1.0000	

TABLE 5.1 REDUCED DATA FOR 0-5000 FT., FROM TABLE 5.0

To determine the initial parameters for the Weibull distribution, eqn (6), a U vs W transformation was used. This allowed for an initial estimate of the Weibull parameters, α , and β. The transformation was developed as follows:

$$F(V) = 1 - \exp\left[-\left(\frac{V-\gamma}{\beta-\gamma}\right)^{\alpha}\right]$$

$$1 - F(V) = \exp\left[-\left(\frac{V-\gamma}{\beta-\gamma}\right)^{\alpha}\right]$$

$$\ln(1-F(V)) = -\left(\frac{V-\gamma}{\beta-\gamma}\right)^{\alpha}$$

$$-\ln(1-F(V)) = \left(\frac{V-\gamma}{\beta-\gamma}\right)^{\alpha}$$

$$\alpha \ln\left(\frac{V-\gamma}{\beta-\gamma}\right) = \ln\left[-\ln(1-F(V))\right]$$

$$\alpha \ln(V-\gamma) - \alpha \ln(\beta-\gamma) = \ln\left[-\ln(1-F(V))\right]$$

But the equation of a straight line is

$$u = mw + b$$

where m is the slope of the line
b is the u intercept when W = 0

let $W = \ln(V-\gamma)$

and $u = \ln\left[-\ln(1-F(V))\right]$.

Therefore;

$$u = \boxed{m}\ W + \boxed{b}$$
$$u = \boxed{\alpha}\ W \boxed{-\alpha \ln(\beta-\gamma)} \qquad (13)$$

where α is the slope
and $-\alpha \ln(\beta-\gamma)$ is the u intercept when W = 0

* Any Weibull function in a u vs W domain is a straight line.

Table 5.2 lists the results of the u vs W transformation where the nominal velocities were input for V, and cumulative probabilities, from column 3, were input for F(V). These values were then plotted in the u vs W domain, (Fig 2) and a straight line was drawn through the most significant points that represented individual probabilities, from eqn 12, of greater than .05. From this straight line the parameters were derived as follows:

F-15 PRESENT FLEET

VELOCITY (KTS)	NOMINAL VELOCITY (KTS)	CUM PROB	U	W
90 - 120	105	.0001	-9.2103	4.1744
120 - 150	135	.0003	-8.1116	4.5539
150 - 180	165	.1066	-2.1828	4.8283
[illegible]30 - 210	195	.2174	-1.4060	5.0434
[illegible]0 - 240	225	.3291	-.9185	5.2204
240 - 270	255	.4350	-.5605	5.3706
270 - 300	285	.5213	-.3056	5.5013
300 - 330	315	.6368	.0127	5.6168
330 - 360	345	.7708	.3874	5.7203
360 - 390	375	.8461	.6267	5.8141
390 - 420	405	.9312	.9845	5.8999
420 - 450	435	.9625	1.1889	5.9789
450 - 480	465	.9753	1.3086	6.0521
480 - 510	495	.9808	1.3744	6.1203
510 - 540	525	.9863	1.4564	6.1841
540 - 570	555	.9924	1.5851	6.2442
570 - 600	585	.9957	1.6955	6.3008
600 - 630	615	.9978	1.8114	6.3544
630 - 660	645	.9994	1.0040	6.4052
660 - 690	675	.9999	2.2203	6.4536
690 - 720	705	1.0000	2.4435	6.4998

DATA FROM STRUCTURAL RECORDER (HOLLOMAN, BITBURG, KADENA)

TABLE 5.2 WEIBULL U VS W TRANSFORMATION

α = slope of line = 2.81

from graph, u = -15.7002 when W = 0

γ = 40 established prior to u vs W transformation

Then

$$-15.7002 = 2.81(0) - 2.81 \ln(\beta - 40)$$

$$\beta = 307$$

$$F(V)_1 = 1 - \exp\left[-\left(\frac{V-40}{307-40}\right)\right]^{2.81} \qquad \text{for } 200 < V \leq 720$$

The correction factor (γ) in the u vs W domain straightens the data somewhat to represent a straight line. The value for γ was determined by trial and error, as γ was incremented from 0 - 140, and then finally chosen as 40, since it provided the best fit to the data sample.

The above Weibull distribution fitted the data sample exceptionally well from 200 to 720 knots, but was unrealistic below 200 knots. Therefore, the range 110 - 200 was fitted with a sixth order equation.

This distribution was developed by approximating that range by a realistic distribution and intersecting the Weibull at the most common point, which for this case was 200 knots. Then from this distribution, a sixth order least squares fit was accomplished, and the equation checked to insure that the distribution for the specified range was in fact a probability distribution. The following equation was developed:

$$F(V) = \begin{cases} -5.793168 + 2.49687 \times 10^{-1} V - 4.296046 \times 10^{-3} V^2 \\ +3.774985 \times 10^{-5} V^3 - 1.792476 \times 10^{-7} V^4 \\ + 4.396387 \times 10^{-10} V^5 - 4.371459 \times 10^{-13} V^6 \end{cases} \qquad \text{for } 116 \leq V \leq 200$$

Figure 3 summarizes the F-15 present fleet velocity profile in the altitude range of 0 - 5000 ft AGL.

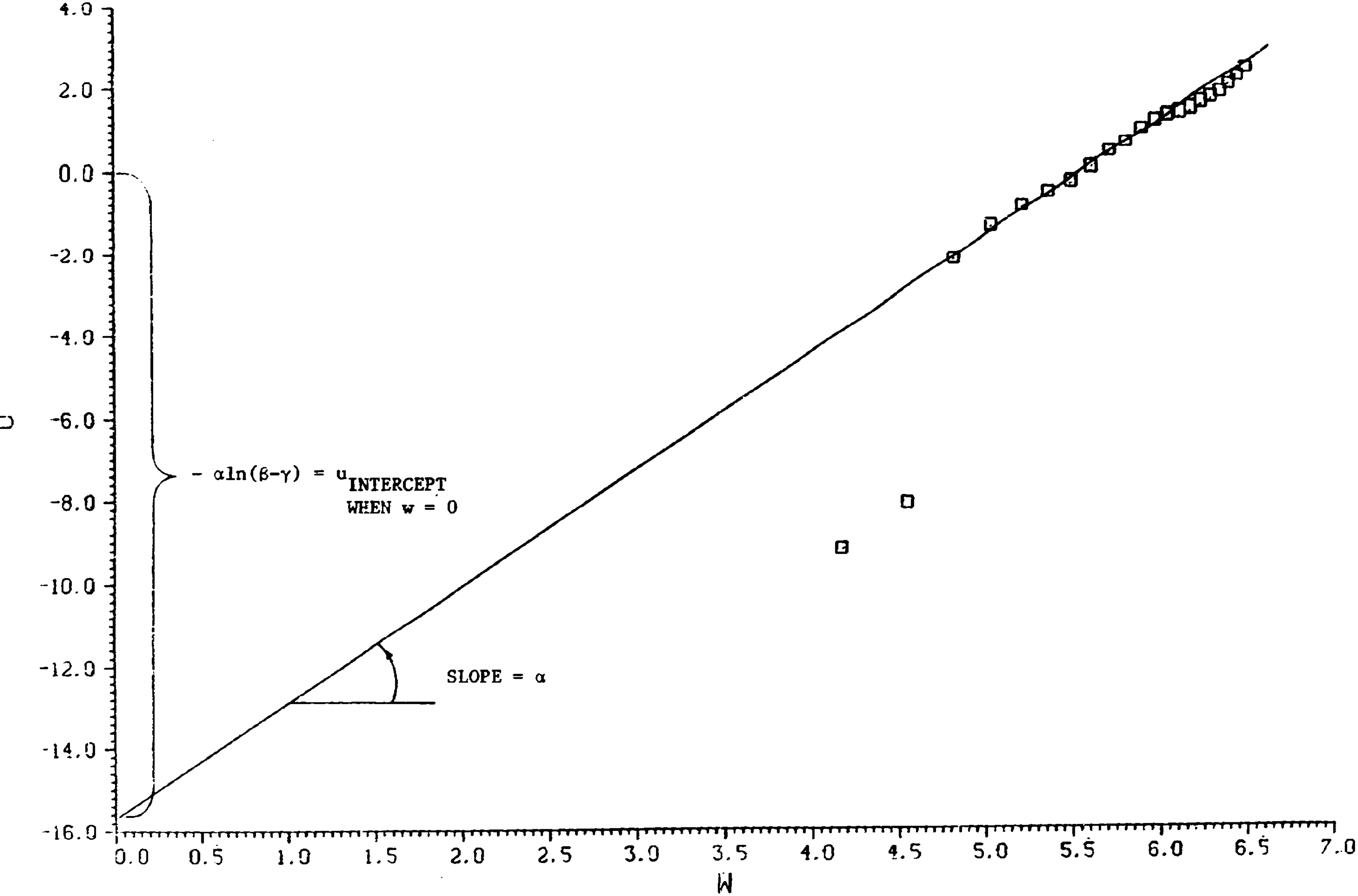


FIG. 2 U VS W TRANSFORMATION
F-15 PRESENT FLEET, AIR TO AIR MISSION

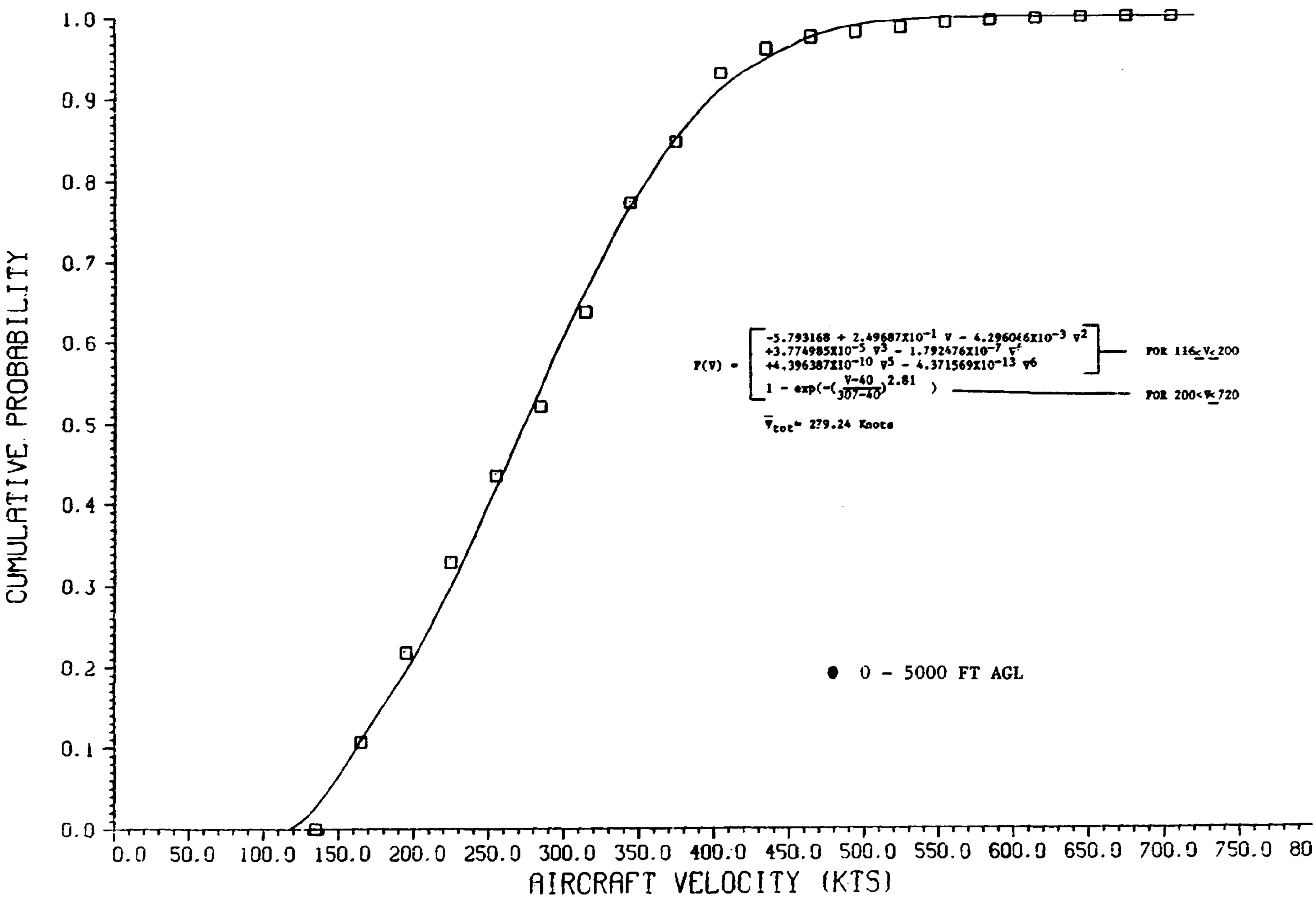


FIG. 3 F-15 PRESENT FLEET VELOCITY DISTRIBUTION
AIR TO AIR MISSION FROM STRUCTURAL RECORDER DATA

The mean velocity was obtained by applying eqn 9 and 10. By using a numerical integration subroutine on an HP-15C, the mean velocity for the F-15 present fleet was determined to be 279.24 knots.

The proportion of time (t_s) in the range of 0 - 5000 ft AGL for CONUS was obtained from McDonnell Douglas structural loads report (MDC A5318) for all missions other than air to ground. The t_s was determined to be .1198, based on mission mix as specified on pg 3.2.2.1 of the above report. The reason for not using the Holloman t_s was that it was unrealistic and it contradicted a data sample from Langley. The t_s for Holloman was approximately .04 and Langley, .14. Therefore, as a last resort, the structural loads report was used.

Bitburg data was used to determine the t_s for Europe. From Bitburg data for Europe, the t_s was evaluated to be .2307. This represented a realistic value since historically the F-15 fleet has spent considerably more time in Europe between 0 - 5000 ft, and another source of data matched the above t_s within .01 (1%).

An assumption was made that the velocity profile for the present fleet, in the range of 0 - 5000 ft AGL, was the same between CONUS and Europe. This was done considering that the mean velocity would not increase or decrease by more than 10 knots. Such a change in this analysis represents insignificant changes in final results.

F-15 RAPID DEPLOYMENT FORCE (RPD) VELOCITY DISTRIBUTION

For the F-15 RPD, the air to ground velocity profile was derived from McDonnell Douglas structural load report (MDC A5318). This data was used since the F-15 does not fly an air to ground mission at this time. The above report, although not labeled F-15 RPD, is representative of the RPD, since the RPD will be the basic F-15C aircraft with provisions for conformal fuel tanks and a requirement for an air to ground mission (based on conversations with McDonnell Douglas).

Table 6.0-6.3 summarizes the Air to Ground missions for the F-15 RPD. Similar methods were used to reduce the data as in the previous section; however, some reorganization of data was necessary to fit the data with a Wiebull curve. For example, if a data point was reduced to be at 443 knots, then this point was assigned to a velocity range of 410 - 460 knots and for Weibull fitting purposes the nominal point between 410 - 460 was used. This approach allowed for some inaccuracy in the source of data. To these boundaries, the Weibull distribution could have been fitted, iterating as necessary to insure most important points are intersected or very closely approached. Important points for this case are defined as points for which eqn 12 shows values of .15 or greater (this value can be established by using one's judgment).

Figure 4 summarizes the F-15 RPD velocity profile for an altitude range of 0 - 5000 ft AGL. An assumption was made that the same velocity profile is flown between CONUS and Europe. Further, it was assumed that for 0 - 5000 ft AGL, the F-15 RPD will fly the same air to air velocity profile in CONUS and Europe as the present fleet (Fig 3). Same rationale as previous section.

F-15C(CFT)
MISSION SUMMARY

	MISSION	MISSION HRS PER LIFETIME	HRS PER MISSION	NUMBER OF MISSIONS	COMBAT HRS PER MISSION	COMBAT HRS PER LIFETIME
	Air-toAir 1	310	1.7334	179	.0306	5.5
	Air-to-Air 3	545	1.1905	458	.2334	106.9
	DOC*	90	.7591	119	.1790	21.3
	ESM*	360	2.6054	138	.0732	10.1
Mix Used	Air-to-Ground 1	665	1.217	546	.499	272.4
Mix Used	Air-to-Ground 2A	300	.912	329	.333	109.6
Mix Used	Air-to-Ground 2B*	385	1.1329	340	.2156	73.3
	Formation/Acrobatics 1A	85	1.2486	68	.1576	10.7
	Formation/Acrobatics 1B*	130	2.2116	59	.1536	9.0
	Instrument/Navigation 1A	500	3.789	132	--	--
	Instrument/Navigation 1B*	405	5.4035	75	--	--
	Ferry*	225	6.5976	34	--	--

*Indicates Missions with Conformal Fuel Tanks

Above missions represent a 400 Hr aircraft lifetime

TOTAL COMBAT TIME PER LIFETIME = 618.8 HR
AIR-TO-AIR COMBAT TIME PER LIFETIME = 163.5 HR
AIR-TO-GROUND COMBAT TIME PER LIFETIME = 455.3 HR

DATA OBTAINED FROM MCDONNELL DOUGLAS REPORT #MDC-A5318

TABLE 6.0 F-15 RAPID DEPLOYMENT FORCE MISSION MIX FOR THE AIR TO GROUND MISSION

F-15C

AIR-TO-GROUND 1

PAYLOAD: 4 AIM-7F + Internal Gun + Ammo + 4000 lbs. Bombs
FUEL: Full Internal PEP + Full External £ 600 Gal. Tank

SEGMENT	OPERATION	ALTITUDE (FT)	WEIGHT (LBS)	FUEL (LBS)	DISTANCE (N.M.)	MACH	TIME (HR)
		SL	53479				
A	Ground Operation and Take-Off			800 300	- 4	- .30	.100 .017
		SL	52379				
B	Ascent: Climb to 5K			160	3	.483	.008
		5000	52219				
	Cruise: Speed for Best Range			2027	100	.562	.274
		5000	50192				
D	Combat: Drop Bombs Expend Ammo		(4282)	12076	-	.70	.499
		SL	33834				
E	Ascent: Climb to Alt. for Best Cruise			1080	51	.841	.103
		48000	32754				
F	Cruise: Mach for Best Range			None	None	-	-
		48000	32754				
G	Descent: To SL 70% RPM			475	56	.595	.183
		SL	32279				
H	Landing 5% Internal Fuel			682	-	-	.003
		SL	31597				1.217

DATA OBTAINED FROM MCDONNELL DOUGLAS REPORT #MDC-A5318

TABLE 6.1 F-15 RAPID DEPLOYMENT FORCE AIR-TO-GROUND 1 MISSION

F-15C

AIR-TO-GROUND 2A

PAYLOAD: 4 AIM-7F + Internal Gun + Ammo + 4000 Lbs. Bombs
FUEL: Full Internal PEP + Full External ℄ 600 Gal. Tank

SEGMENT	OPERATION	ALTITUDE (FT)	WEIGHT (LBS)	FUEL (LBS)	DISTANCE (N.M.)	MACH	TIME (HR)
		SL	53479				
A	Ground Operation and Takeoff			800 300	- 2	- .3	.100 .017
		SL	52379				
B	Ascent: Climb to 500 Ft.			53	1	.329	.003
		500	52326				
C1	Accelerate: M = .54 - .90			421	8	.90	.018
		500	51905				
C2	Cruise: M = .90 at 500 Ft.			3866	116	.90	.194
		SL	48039				
D	Combat: 20 Min at Mil Power		(4282)	8066	-	.70	.333
		500	35691				
E	Cruise: M = .90 at 500 Ft.			3412	127	.90	.214
		500	32279				
F	Descent:			-	-	.875	-
		SL	32279				
G	Landing: Fuel Reserve			682	-	-	.033
		SL	31597				.912

DATA OBTAINED FROM MCDONNELL DOUGLAS REPORT #MDC-A5318

TABLE 6.2 F-15 RAPID DEPLOYMENT FORCE AIR-TO-GROUND 2A MISSION

F-15 (CFT)

AIR-TO-GROUND 2B

PAYLOAD: 4 AIM-7F + Internal Gun + Ammo + 6000 Lbs. Bombs (MK-82)
FUEL: Full Internal PEP + Full Conformal Fuel Tanks

SEGMENT	OPERATION	ALTITUDE (FT)	WEIGHT (LBS)	FUEL (LBS)	DISTANCE (N.M.)	MACH	TIME (HR)
		SL	63499				
A	Ground Operation			920	-	-	.100
	Take-Off (Mil Power)			550	1.0	.53	.0083
		SL	62029				
B	Ascent: Climb To 500 Ft			75	1.0	.53	.004
		500	61954				
C1	Accelerate: M = .54 - .90			382	7.6	.72	.0156
		500	61572				
C2	Cruise: Constant Alt. @ M = .90			7938	220.	.90	.370
		500	53634				
D	Combat: Mil Power Drop Bombs, Ammo		(6282)	5218	-	.70	.2156
		500	42134				
E	Cruise: Constant Alt. @ M = .90			7735	229.6	.90	.386
		500	34399				
F	Descend: To SL			-	-	.90	-
		SL	34399				
G	Landing: 5% Fuel Reserve			682	-	-	.0334
		SL	33717				1.1329

DATA OBTAINED FROM MCDONNELL DOUGLAS REPORT # MDC-A5318

TABLE 6.3 F-15 RAPID DEPLOYMENT FORCE AIR-TO-GROUND 2B

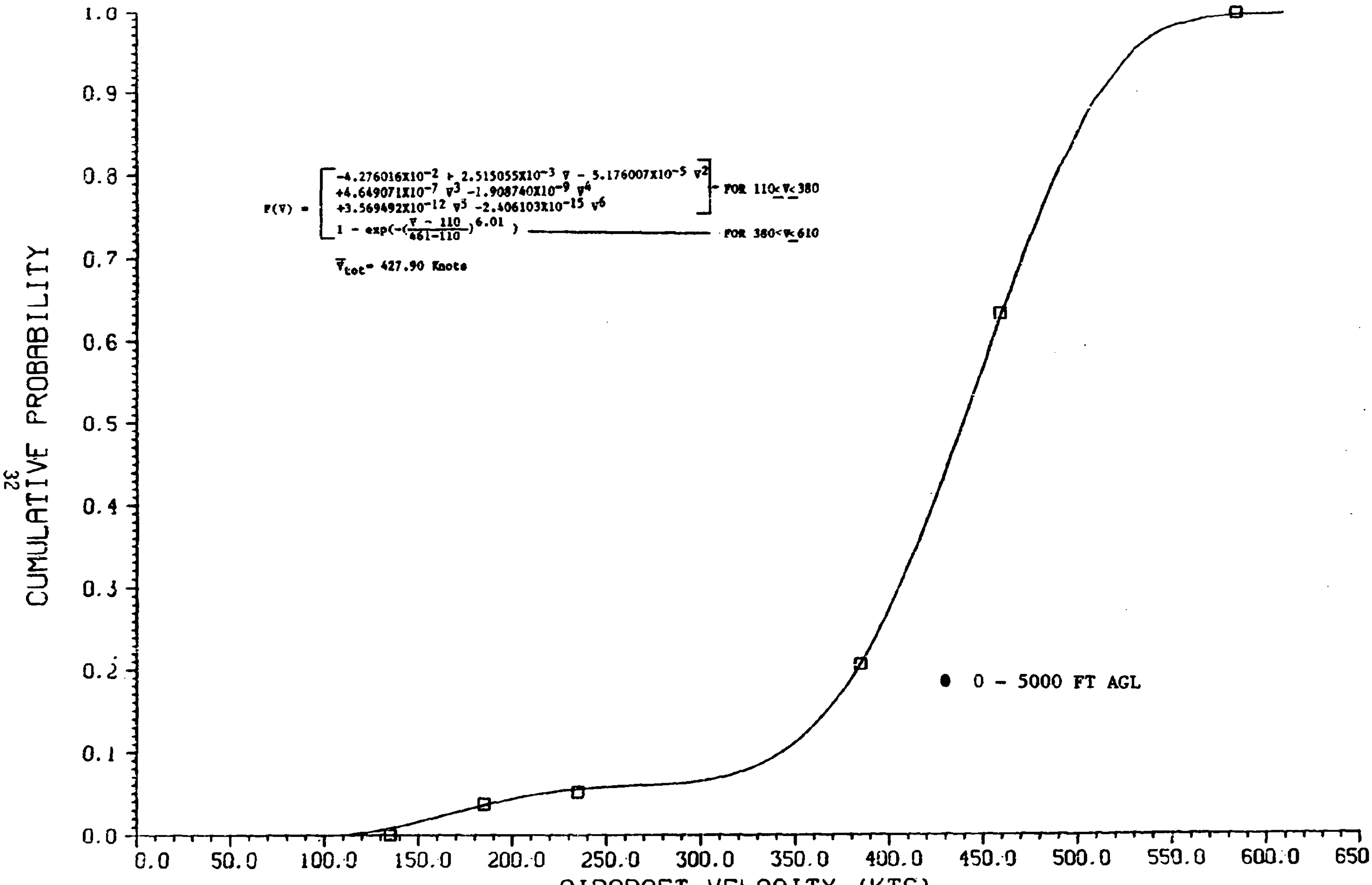


FIG. 4 F-15 RPD VELOCITY DISTRIBUTION
AIR TO GROUND MISSION FROM STRUCTURAL LOAD REPORT

F-15 DUAL ROLE FIGHTER VELOCITY DISTRIBUTION

The F-15 Dual Role Fighter (DRF), air to ground (0 - 500 ft AGL) velocity profile was derived from McDonnell Douglas Structural Design Criteria, Memorandum 199-DRF-169. This report was used, since it was the best source of this type of information for the DRF.

Mission mix was obtained from the same report and is summarized as follows:

F-15 DRF MISSION MIX

AIR-TO-AIR	20%	A/A1	2.5%
		A/A2	2.5%
		A/A3	15.0%
AIR-TO-GROUND	75%	A/G1	10.0%
		A/G2	10.0%
		A/G3	55.0%
NON-TACTICAL	5%	N/T1	2.5%
		N/T2	2.5%

NOTE (A) Based on a 4000 hour aircraft lifetime

(B) All percentages are percent of total missions

Table 7.0 - 7.2 lists each air to ground mission. In data reduction, only flight in the altitude range of 0 - 5000 ft is considered. A ratio is used for climbs and descents up to 5000 ft. Same methods were used as in the previous sections to fit the data with a Weibull and sixth order distribution.

Figure 5 summarizes the F-15 DRF velocity profile for an altitude range of 0 - 5000 ft AGL. Similarly as for the F-15 RPD, it was assumed that the DRF will fly the same velocity profile (0 - 5000 ft) between CONUS and Europe. The DRF air to air velocity profile (0 - 5000 ft) was assumed to be equivalent to the F-15 present fleet between CONUS and Europe. Same rationale as previous sections.

F-15 DRF
AIR-TO-GROUND I

PAYLOAD: 4 AIM-7F + 4 AIM-9L + Internal Gun + Ammo + 5000 lbs. Bombs + LANTIRN
FUEL: Full Internal +Full CFT + Full £ 600 Gal. Tank

SEGMENT	OPERATION	ALTITUDE (FT)	WEIGHT (LBS)	FUEL (LBS)	DISTANCE (N.M.)	MACH	TIME (HR)
		SL	71887				
A	Ground Operation And Take-Off Max AB			800 550	- 2.0	- .30	.100 .017
		SL	70537				
B	Ascent: Climb to 5K			375	3.0	.483	.008
		5000	70162				
C	Cruise: Speed for Best Range			9372	305	.625	.7515
		5000	60790				
D	Dash			2239	50.0	.90	.0856
		5000	58551				
E	Combat: Drop Bombs Expend Ammo		(5120)	8200	-	.80	.3333
		SL	45231				
F	Ascent: Climb to Alt. for Best Cruise			1950	80.0	.85	.25
		40000	43281				
G	Cruise: Mach for Best Range			2234	195	.86	.3944
		40000	41047				
H	Descent: To SL 70% RPM			540	84.	.595	.200
		SL	40507				
I	Landing 5% Internal Fuel			664	-	-	.0334
		SL	39843				2.1732

DATA OBTAINED FROM MCDONNELL DOUGLAS STRUCTURAL DESIGN CRITERIA, MEMORANDUM 199-DRF-169

TABLE 7.0 F-15 DUAL ROLE FIGHTER AIR-TO-GROUND I MISSION

F-15 DRF
AIR-TO-GROUND 2

PAYLOAD: 2 AIM-7F + Internal Gun + Ammo + 8000 lbs. Bombs + 4 AIM-9 + LANTIRN Pods
FUEL: Full Internal + Full CFT

SEGMENT	OPERATION	ALTITUDE (FT)	WEIGHT (LBS)	FUEL (LBS)	DISTANCE (N.M.)	MACH	TIME (HR)
		SL	70082				
A	Ground Operation			504	-	-	.100
	Takeoff			300	2.0	.53	.0167
		SL	69278				
B	Ascent: Climb to 5000 Ft.			375	3.0	350/.9	.008
		5000	68903				
C	Cruise: Opt. Speed			2612	85	.625	.2095
		5000	66291				
D	Descend: to SL No Range or Fuel			-	-	-	.025
		SL	66291				
E	Dash: Constant Alt. @ .82			4597	100	.82	.1848
		SL	61694				
F	Combat: Mil Power Drop Bombs		(8000)	8000	-	.80	.3333
		SL	45694				
G	Dash: Constant Alt. @.82			4040	100	.82	.1848
		SL	41654				
H	Ascent: Climb to 5000 Ft.			125	2.0	.90	.0067
		5000	41529				
I	Cruise: Opt. Speed			1767	84	.48	.2695
		5000	39762				
J	Descend: to SL			45	4.0	.37	.0167
		SL	39717				
K	Landing: 5% Fuel Res.			664	-	-	.0334
		SL	39053				
							1.3884

DATA OBTAINED FROM MCDONNELL DOUGLAS STRUCTURAL DESIGN CRITERIA, MEMORANDUM 119-DRF-169

TABLE 7.1 F-15 DUAL ROLE FIGHTER AIR-TO-GROUND 2 MISSION

F-15 DRF
AIR-TO-GROUND 3

PAYLOAD: 2 AIM-9 + SUU-20 + LANTIRN Pods
FUEL: Full Internal + Full CFT

SEGMENT	OPERATION	ALTITUDE (FT)	WEIGHT (LBS)	FUEL (LBS)	DISTANCE (N.M.)	MACH	TIME (HR)
		SL	59203				
A	Ground Operation			504			.100
	Takeoff			300	2.0	.53	.0167
		SL	58399				
B	Ascent: Mil Power Climb to Opt. Alt.			1950	68.0	350/.90	.1367
		35000	56449				
C	Cruise: Opt: Speed			635	49	.915	.0932
		36000	55814				
D	Descent: to 500 ft.			210	34	.68	.1167
		500	55604				
E	Dash: Constant Altitude			4305	150.	.727	.3125
		500	51299				
F	Combat: Drop Bombs		(284)	8200	-	.90	.3333
		500	42815				
G	Dash: Constant Altitude			4268	150	.727	.3125
		500	38547				
H	Ascent: Mil Climb to Opt. Alt.			1375	68	.90	.1233
		43000	37172				
I	Cruise: Opt. Speed			358	41	.915	.0779
		44000	36814				
J	Descent: to SL-Idle Thrust			260	44	.80	.1417
		SL	36554				
K	Landing:				-		
	5% Int. Fuel			664	-	-	.0334
		SL	35890				
							1.7979

DATA OBTAINED FROM MCDONNELL DOUGLAS STRUCTURAL DESIGN CRITERIA, MEMORANDUM 199-DRF-169

TABLE 7.2 F-15 DUAL ROLE FIGHTER AIR-TO-GROUND 3 MISSION

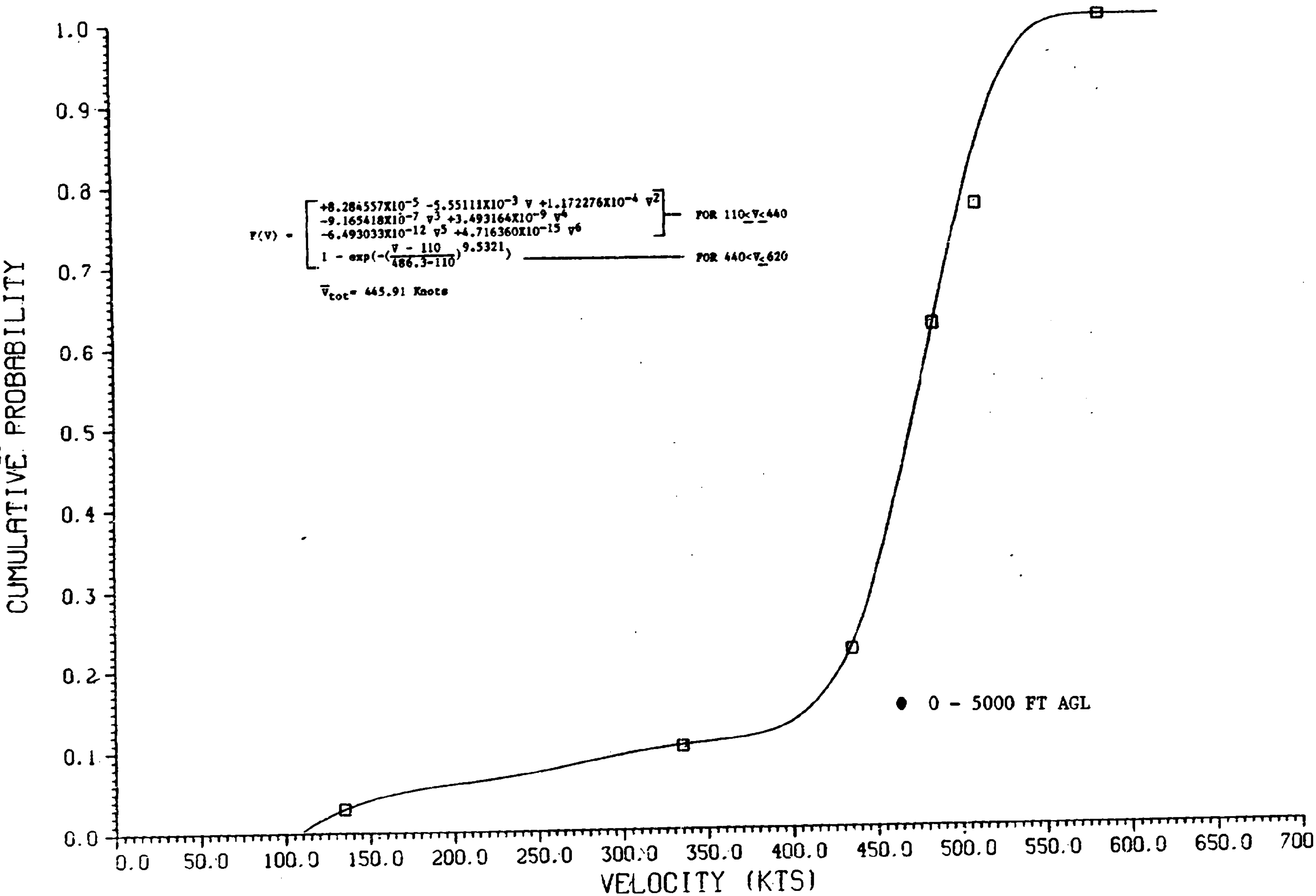


FIG. 5 F-15 DRF VELOCITY DISTRIBUTION
AIR TO GROUND MISSION FROM STRUCTURAL LOAD REPORT

BIRD WEIGHT DISTRIBUTIONS

Bird weight distributions for CONUS and Europe were derived from F-15, F-4 and F-111, (as well as other USAF inventory aircraft, Table 8.0) bird impacts which were identified by species and weight. The above data was obtained from Lt Will (AV 970-6243), BASH Team, Tyndall AFB.

The bird impact data is summarized in Tables 8.0 - 8.6. Table 8.0 lists a composite of several aircraft bird impacts which were identified by the Smithsonium Institute. Some identified bird weights are exact and some are averaged. F-15, F-4, and F-111 impacts were extracted from the log book data and listed in Table 8.1 - 8.6 with remaining computer file bird impacts. All bird impacts are impacts that have been reported anywhere on the aircraft. A bird impacting a wing or engine could have just as well hit the windshield or canopy. The data from computer files was identified by bird type, then Reference 3-5 was used to associate a bird type with a bird weight. Reference 3 was considered to be the most exact source of information, then reference 4 and finally Reference 5 as a last resort.

Based on Tables 8.0 - 8.6 for CONUS and Europe, the data was reduced using eqn 12 and then fitted with a Weibull distribution or a mixture of distributions. Figures 6 and 7 summarize the results with appropriate equations defining each distribution, as well as the mean bird weights.

COMPOSITE OF SEVERAL AIRCRAFT CONUS

BASE	STRIKE DATE	A/C	BIRD TYPE	BIRD WEIGHT
K.I. Sawyer	82/05	B-52H	Horned Lark	1.25 - 1.50 oz
Buckley Field	82/05	A-7D	Red Tailed Hawk	2.5 lbs
Columbus	82/05	T-38	Turkey Vulture	4.5 lbs
MacDill	82/05	F-16	White Ibis	1.5 lbs
Hill	82/05	F-16	White Pelican	17 lbs
Buckley Field	82/06	T-43A	Red Tailed Hawk	2.5 lbs
Williams	82/06	T-38	Horned Lark	1.25 - 1.5 oz
Myrtle Beach	82/06	A-10	Turkey Vulture	4.5 lbs
MacDill	82/07	F-16A	Black Vulture	4.5 lbs
Laughlin	82/07	T-38A	Black Vulture	4.5 lbs
Williams	82/07	T-38	Horned Lark	1.25 - 1.5 oz
K.I. Sawyer	82/07	B-52H	Red Tailed Hawk	2.5 lbs
Patrick	82/08	A-10	Magnificent Frigate Bird	3 lbs
Barnes MAP (ANG)	82/08	A-10	Red Tailed Hawk	2.5 lbs
Columbus	82/07	T-38	Eastern Meadow Lark	4 oz
Ellsworth	82/11	B-52H	Sanderling	1.75 oz
Ellsworth	82/12	B-52H	Golden Eagle	9 lbs
Blytheville	82/04	B-52G	Upland Plover	3 - 3.5 oz
McClellan	82/04	HC-130	Horned Lark	1.25 oz - 1.5 oz
Dyess	82/01	C-130	Robin	3 oz
Minot	82/06	F-106	Horned Lark	1.25 oz - 1.5 oz
Vance	82/06	T-37	Western Meadowlark	4 oz
Luke	82/09	F-104	White Throated Swift	1 oz
Laughlin	82/09	T-38	Black Vulture	4.5 lbs
K.I. Sawyer	82/10	B-52H	Red Winged Blackbird	1.5 oz - 2.0 oz
Columbus	82/09	T-38A	Cattle Egret	12 oz
Columbus	82/09	T-38A	Turkey Vulture	4.5 lbs
Grissom	82/09	KC-135A	Killdeer	3 oz
Norton	82/10	C-141B	Coot	1.25 lbs
Myrtle Beach	82/10	A-10	Red Tailed Hawk	2.5 lbs
Williams	82/10	T-38A	Horned Lark	1.25 oz - 1.5 oz
K.I. Sawyer	82/10	B-52H	Black Vulture	4.5 lbs

TABLE 8.0 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

COMPOSITE OF SEVERAL AIRCRAFT CONUS (Continued)

BASE	STRIKE DATE	A/C	BIRD TYPE	BIRD WEIGHT
Vance	82/11	T-38	Wood Duck	1.5 lbs
Williams	82/11	T-38A	Horned Lark	1.25 oz - 1.5 oz
Williams	82/12	T-38A	American Kestrel	3 oz
Vance	82/12	T-38A	Meadow Lark	4 oz
Rickenbacker (ANG)	82/12	A-7D	Red Tailed Hawk	2.5 lbs
Columbus	82/12	T-38A	Common Grackle	3 - 4 oz
Pope	82/12	C-130E	Ring Necked Duck	1.5 lbs
Myrtle Beach	82/12	A-10A	Ring Necked Duck	1.5 lbs
Des Moines MAP (ANG)	83/01	A-7D	Meadow Lark	4 oz
Williams	83/01	T-38A	Horned Lark	1.25 - 1.5 oz
MacDill	83/01	F-16B	Bald Eagle	8 lbs
Hill	83/01	F-16A	White Pelican	10 - 17 lbs
Myrtle Beach	83/01	A-10A	Laughing Gull	9.1 - 11.50 oz
Williams	83/01	T-38A	Horned Lark	1.25 - 1.5 oz
Savanah MAP (ANG)	83/03	C-130H	Osprey	3.5 lbs
Rickenbacker (ANG)	83/03	A-7D	Red Shouldered Hawk	1.75 lbs
Minot	83/03	B-52H	Pintail Duck	2.2 lbs

DATA OBTAINED FROM LOG BOOK OF IDENTIFIED BIRD TYPE AND WEIGHT BY SMITHSONIUM INSTITUTE, BASH TEAM, TYNDALL AFB; LT WILL (AV 970-6243), LOG BOOK CALL #'s 204-293.

TABLE 8.0 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-15 CONUS

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Langley	76/04	F-15A	TAC	Laughing Gull	9.1 - 11.5 oz
Langley	76/08	F-15A	TAC	Laughing Gull	9.1 - 11.5 oz
Langley	76/08	F-15A	TAC	Laughing Gull	9.1 - 11.5 oz
Langley	78/04	F-15A	TAC	Rough-Legged Hawk	2.0 lbs
Langley	79/02	F-15	TAC	Herring Gull	2.5 lbs
Langley	79/03	F-15	TAC	Herring Gull	2.5 lbs
Langley	79/04	F-15	TAC	Herring Gull	2.5 lbs
Langley	79/05	F-15	TAC	Laughing Gull	9.1 - 11.5 oz
Langley	79/08	F-15	TAC	Laughing Gull	9.1 - 11.5 oz
Langley	79/08	F-15A	TAC	Sparrow Hawk	.5 lbs
Langley	79/08	F-15	TAC	Sparrow	.8 oz
Eglin	80/02	F-15A	TAC	Sparrow	.8 oz
Langley	80/02	F-15	TAC	Red Winged Blackbird	3.3 oz
Luke	80/02	F-15B	TAC	Red Winged Blackbird	3.3 oz
Langley	80/03	F-15	TAC	Ring Billed Gull	1.5 lbs
Langley	80/04	F-15	TAC	Double Crested Cormorant	4.5 lbs
Luke	80/07	F-15B	TAC	Mourning Dove	5.5 oz
Langley	81/11	F-15	TAC	Sandpiper	.125 lbs
Langley	81/11	F-15C	TAC	American Kestrel	3 oz
Langley	81/12	F-15A	TAC	Herring Gull	2.5 lbs
Langley	81/12	F-15A	TAC	Dunlins	.25 lbs
Langley	82/02	F-15C	TAC	Common Grackle	3 - 4 oz
Langley	82/07	F-15C	TAC	Sparrow	.8 oz
Luke	82/07	F-15	TAC	Mourning Dove	5.5 oz
Langley	82/07	F-15D	TAC	Common Grackle	3 - 4 oz
Langley	82/08	F-15A	TAC	Sparrow	.8 oz
Langley	82/09	F-15C	TAC	Common Grackle	3 - 4 oz
Langley	82/09	F-15C	TAC	Common Grackle	3 - 4 oz
Langley	82/10	F-15A	TAC	Herring Gull	2.5 lbs
Langley	82/11	F-15C	TAC	Herring Gull	2.5 lbs
Luke	82/12	F-15	TAC	Water Pipit	.8 oz
Holloman	83/03	F-15B	TAC	Golden Eagle	14 lbs
Luke	83/04	F-15A	TAC	Redwinged Blackbird	3.3 oz

DATA FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES

TABLE 8.1 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-15 EUROPE

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Unknown	78/09	F-15A	AFE	Lapwing	8 oz
Unknown	79/06	F-15A	AFE	Kestrel	8 oz
Camp New Amsterdam	80/05	F-15A	AFE	Magpie	7.4 oz
Camp New Amsterdam	80/05	F-15A	AFE	Seagull	8 oz
Camp New Amsterdam	80/05	F-15B	AFE	Magpie	7.4 oz
Camp New Amsterdam	80/06	F-15A	AFE	Hawk	2.0 lbs
Camp New Amsterdam	80/06	F-15A	AFE	Hawk	2.0 lbs
Camp New Amsterdam	80/08	F-15C	AFE	Finch	1.0 oz
Camp New Amsterdam	80/08	F-15C	AFE	Kestrel	8 oz
Camp New Amsterdam	80/09	F-15C	AFE	Kestrel	8 oz
Camp New Amsterdam	80/10	F-15C	AFE	Magpie	7.4 oz
Bitburg	80/10	F-15A	AFE	Raven	8 oz
Bitburg	81/05	F-15C	AFE	Buzzard	1.7 - 2.3 lbs
Bitburg	81/05	F-15C	AFE	Sparrow	.8 oz
Bitburg	81/05	F-15C	AFE	Buzzard	1.7 - 2.3 lbs
Bitburg	81/05	F-15C	AFE	Buzzard	1.7 - 2.3 lbs
Bitburg	81/05	F-15C	AFE	Green Finch	1.0 oz
Unknown	81/07	F-15C	AFE	Sparrow	.8 oz
Camp New Amsterdam	81/09	F-15D	AFE	Magpie	7.4 oz
Camp New Amsterdam	81/09	F-15D	AFE	Magpie	7.4 oz
Bitburg	82/05	F-15C	AFE	Swift	1.3 oz
Camp New Amsterdam	82/09	F-15C	AFE	Lapwing	8 oz
Bitburg	82/09	F-15C	AFE	Lapwing	8 oz

DATA FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES

TABLE 8.2 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-4 CONUS

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Bergstrom	75/05	RF-4C	TAC	Turkey Vulture	4.5 lbs
Bergstrom	75/06	RF-4C	TAC	Turkey Vulture	4.5 lbs
Eglin	75/06	F-4E	TAC	Buzzard	1.7 - 2.3 lbs
Bergstrom	75/11	RF-4C	TAC	Gadwall Duck	1 1/2 lbs
Eglin	75/12	F-4C	SYSTEMS	Sparrow Hawk	.5 lbs
Duluth IAP MN	76/03	RF-4C	ANG	Snow Bunting	.8 oz
Bergstrom	76/05	RF-4C	TAC	Turkey Vulture	4.5 lbs
MacDill	76/05	F-4E	TAC	Cattle Egret	12 oz
Hill	76/05	RF-4C	LOG	Cattle Egret	12 oz
Moody	76/06	F-4E	TAC	Cattle Egret	12 oz
Homestead	76/10	F-4E	TAC	Black Buzzard	1.7 - 2.3 lbs
Homestead	77/02	F-4E	TAC	Black Vulture	4.5 lbs
Duluth IAP MN	77/04	RF-4C	ANG	Duck	1 1/2 lbs
Seymour Johnson	77/07	F-4E	TAC	Turkey Buzzard	1.7 - 2.3 lbs
Homestead	77/09	F-4E	TAC	Cattle Egret	12 oz
Homestead	77/09	F-4E	TAC	Cattle Egret	12 oz
Unknown	78/02	F-4E	TAC	Robin	3 oz
MacDill	78/03	F-4E	TAC	Pelican	10 - 17 lbs
Lincoln MAP NE	78/03	RF-4C	ANG	Pintail Duck	1 1/2 lbs
Birmingham Muni	78/04	RF-4C	ANG	Turkey Buzzard	1.7 - 2.3 lbs
Unknown	78/05	RF-4C	ANG	White Pelican	10 - 17 lbs
Homestead	78/06	F-4E	TAC	Turkey Vulture	4.5 lbs
George	78/06	F-4E	TAC	Sparrow	.8 oz
MacDill	78/08	F-4D	TAC	Pelican	10 - 17 lbs
Unknown	78/09	RF-4C	TAC	Thrush	3 oz
Hill	78/09	F-4D	LOG	Lark	1.25 - 1.5 oz
George	78/10	F-4C	SYSTEMS	Sparrow	.8 oz
Unknown	78/10	F-4E	TAC	C Swift	1.0 oz
Shaw	78/10	RF-4C	TAC	Black Vulture	4.5 lbs
Unknown	78/11	RF-4C	TAC	Robin	3 oz
Unknown	78/12	F-4E	TAC	Turkey Vulture	4.5 lbs

TABLE 8.3 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-4 CONUS (Continued)

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
MacDill	79/03	F-4D	TAC	Pelican	10 - 17 lbs
Duluth IAP MN	79/04	RF-4C	ANG	Raven	1 lb
Unknown	79/04	F-4C	TAC	Sparrow	.8 oz
Seymour Johnson	79/04	F-4E	TAC	Loon	3 1/2 lbs
Unknown	79/05	F-4D	TAC	Sparrow	.8 oz
Hill	79/05	F-4D	TAC	Warbler	.5 oz
Homestead	79/05	F-4C	TAC	Turkey Buzzard	1.7 - 2.3 lbs
Homestead	79/06	F-4E	TAC	Turkey Buzzard	1.7 - 2.3 lbs
Bergstrom	79/07	RF-4C	TAC	Warbler	.5 oz
Bergstrom	79/08	RF-4C	TAC	Red Shouldered Buzzard Hawk	2.5 lbs
MacDill	79/09	F-4D	TAC	Turkey Vulture	4.5 lbs
Unknown	79/09	F-4G	TAC	Sparrow	.8 oz
Key Field MS	79/10	RF-4C	ANG	Buzzard/Turkey Vulture	4.5 lbs
Unknown	79/11	RF-4C	TAC	Mockingbird	3 oz
Homestead	79/11	F-4E	TAC	Turkey Buzzard	1.7 - 2.3 lbs
Unknown	79/11	F-4E	TAC	Cattle Egret	12 oz
Homestead	79/11	F-4C	AFR	Turkey Buzzard	1.7 - 2.3 lbs
George	79/11	F-4E	TAC	Sparrow	.8 oz
George	79/11	F-4E	TAC	Sparrow	.8 oz
George	79/11	F-4E	TAC	Sparrow	.8 oz
George	79/11	F-4E	TAC	Sparrow	.8 oz
Unknown	79/11	F-4C	TAC	Turkey Buzzard	1.7 - 2.3 lbs
Moody	79/12	F-4	TAC	Turkey Vulture	4.5 lbs
Shaw	80/03	F-4C	TAC	Turkey Vulture	4.5 lbs
Lincoln MAP NE	80/04	F-4C	ANG	Common Grackle	3-4 oz
Fort Smith MAP	80/05	F-4C	TAC	Red Tailed Hawk	2.5 lbs
Standiford Field KY	80/05	RF-4C	ANG	Sandpiper	.125 lbs
Homestead	80/06	F-4D	TAC	Turkey Vulture	4.5 lbs
Moody	80/11	F-4E	TAC	Common Loon	3 1/2 lbs
Dannelly Fld	81/01	RF-4C	ANG	Black Buzzard	1.7 - 2.3 lbs
Dannelly Fld	81/03	RF-4C	TAC	Black Buzzard	1.7 - 2.3 lbs
Lincoln MAP NE	81/04	RF-4C	ANG	Plover	.125 lbs

TABLE 8.3 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-4 CONUS (Continued)

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
MacDill	81/05	F-4D	TAC	Crow	1 lb
Duluth IAP MN	81/05	RF-4C	ANG	Plover	.125 lbs
MacDill	81/06	F-4D	TAC	Turkey Vulture	4.5 lbs
Seymour Johnson	81/07	F-4E	TAC	Black Vulture	4.5 lbs
Shaw	81/07	RF-4C	TAC	Red Tailed Hawk	2.5 lbs
MacDill	81/07	F-4D	TAC	Turkey Buzzards	1.7 - 2.3 lbs
Duluth IAP MN	81/07	RF-4C	ANG	Red Tailed Hawk	2.5 lbs
Hill	81/08	F-4E	LOG	Sparrow Hawk	.5 lbs
Unknown	81/10	F-4D	ANG	Mallard Duck	2 lbs
Duluth IAP MN	81/10	RF-4C	TAC	Sparrow	.8 oz
Kelly	81/10	F-4C	ANG	Turkey Vulture	4.5 lbs
Patrick	81/11	F-4	SYSTEMS	Turkey Buzzard	1.7 - 2.3 lbs
Homestead	81/12	F-4C	AFR	Turkey Buzzard	1.7 - 2.3 lbs
Shaw	81/12	RF-4C	TAC	Black Vulture	4.5 lbs
Lincoln MAP NE	82/01	RF-4C	ANG	Canadian Goose	8 lbs
Lincoln MAP NE	82/01	RF-4C	ANG	Mallard Duck	2 lbs
Langley	82/02	F-4C	TAC	Common Grackle	3 - 4 oz
Boise (Gowen Fld) ID	82/04	RF-4C	ANG	Whistling Swan	13.6 - 15.8
Duluth IAP MN	82/04	RF-4C	ANG	Mallard Duck	2 lbs
Dannelly Fld	82/04	RF-4C	ANG	Turkey Vulture	4.5 lbs
Luke	82/05	F-4C	TAC	Red Tailed Hawk	2.5 lb
Homestead	82/05	F-4C	AFR	Turkey Buzzard	1.7 - 2.3 lbs
Birmingham Muni AL	82/06	RF-4C	ANG	Anhinga or Water Turkey	2.5 - 3 lbs
George	82/06	F-4G	TAC	Red Tailed Hawk	2.5 lbs
Wright-Patterson	82/07	F-4D	AFR	Broad Winged Hawk	15 oz
Dannelly Fld	82/07	RF-4C	ANG	Cattle Egret	12 oz
Bergstrom	82/08	RF-4C	TAC	Turkey Vulture	4.5 lbs
Patrick	82/08	F-4	SYSTEMS	Sparrow	.8 oz
Boise (Gowen Fld) ID	82/09	RF-4C	ANG	Sparrow	.8 oz
Lincoln MAP NE	82/09	RF-4C	ANG	Franklins Gull	1/2 - 1 lb
Standiford Field KY	82/10	RF-4C	ANG	Red Tailed Hawk	2.5 lbs
Edwards	82/10	F-4	SYSTEMS	Sparrow	.8 oz

TABLE 8.3 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-4 CONUS (Continued)

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Shaw	82/10	RF-4C	TAC	Sparrow	.8 oz
Birmingham Muni AL	82/11	RF-4C	ANG	American Coot	1 lb
George	82/11	F-4G	TAC	Osprey	3.5 lbs
Moody	82/08	F-4E	TAC	Cattle Egret	12 oz
Moody	82/08	F-4E	TAC	Cattle Egret	12 oz
Moody	82/12	F-4E	TAC	Robin	3 oz
George	82/09	F-4G	TAC	Owl	2 - 4 lbs
McConnell	82/07	F-4	SAC	Killdeer	3 oz
MacDill	83/01	F-4D	TAC	Black Vulture	4.5 lbs
Burlington IAP	83/01	F-4D	ANG	American Kestrel	4 oz
Seymour Johnson	83/02	F-4E	TAC	Raven	2 - 3 lbs

DATA FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES

TABLE 8.3 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-4 EUROPE

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Camp New Amsterdam	75/07	F-4E	AFE	Lapwing	8 oz
Torrejon	75/07	F-4C	AFE	Lesser Bustard	1.53 - 2.15 lbs
Camp New Amsterdam	76/07	F-4E	AFE	Magpie	7.4 oz
Torrejon	77/06	F-4C	AFE	Stork	7 lbs
Unknown	78/02	F-4E	AFE	Killdeer	3 oz
Incirlik	79/05	F-4E	AFE	Stork	7 lbs
Torrejon	79/06	F-4D	AFE	Lark	1.25 - 1.5 oz
Unknown	79/06	RF-4C	AFE	Swift	1 oz
Torrejon	79/07	F-4D	AFE	Lesser Bustard	1.53 - 2.15 lbs
Alconbury	79/11	RF-4C	AFE	Crow	8 oz
Unknown	79/12	RF-4C	AFE	Crow	8 oz
Unknown	80/01	F-4D	AFE	Sparrow	.8 oz
Torrejon	80/03	F-4D	AFE	Sparrow	.8 oz
Torrejon	80/03	F-4D	AFE	Sparrow	.8 oz
Torrejon	80/06	F-4D	AFE	Sparrow	.8 oz
Ramstein	80/08	F-4E	AFE	Swift	1 oz
Incirlik	80/09	F-4E	AFE	Sparrow	.8 oz
Incirlik	80/09	F-4E	AFE	Swallow	.5 oz
Incirlik	80/09	F-4D	AFE	Swallow	.5 oz
Incirlik	81/02	F-4D	AFE	Sparrow	.8 oz
Alconbury	81/02	RF-4C	AFE	Crow	8 oz
Zaragoza	81/03	F-4	AFE	Lapwing	8 oz
Incirlik	81/03	F-4G	AFE	Stork	7 lbs
Incirlik	81/03	F-4G	AFE	Woodlark	1.25 - 1.5 oz
Incirlik	81/04	RF-4C	AFE	Lapwing	1.2 lb
Zaragoza	81/05	F-4	AFE	Magpie	7.4 oz
Incirlik	81/05	F-4D	AFE	Alpine Swift	3 oz
Ramstein	81/05	F-4G	AFE	Swift	1 oz
Ramstein	81/06	F-4E	AFE	Sparrow	.8 oz
Zweibrucken	81/06	RF-4C	AFE	Sparrow	.8 oz
Incirlik	81/06	F-4D	AFE	Calandra Lark	1.25 - 1.5 oz
Incirlik	81/06	F-4D	AFE	Common Swift	1 oz

TABLE 8.4 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-4 EUROPE (Continued)

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Incirlik	81/06	F-4D	AFE	Common Swift	1 oz
Incirlik	81/07	F-4E	AFE	Calandra Lark	1.25 - 1.5 oz
Hahn	81/07	F-4E	AFE	Common Buzzard	1.75 lbs
Incirlik	81/08	F-4E	AFE	White Stork	7 lbs
Incirlik	81/08	F-4E	AFE	Rock Dove	10 oz
Incirlik	81/08	F-4E	AFE	White Stork	7 lbs
Incirlik	81/08	F-4E	AFE	White Stork	7 lbs
Incirlik	81/09	F-4E	AFE	White Stork	7 lbs
Torrejon	81/10	F-4D	AFE	Rock Dove	10 oz
Zaragoza	82/02	F-4	AFE	Sparrow	.8 oz
Incirlik	82/04	F-4D	AFE	Chough	10 oz
Zaragoza	82/05	F-4E	AFE	Griffon Vulture	12 lbs
Spangdahlem	82/05	F-4G	AFE	Common Buzzard	1.75 lbs
Incirlik	82/05	F-4D	AFE	Swift	1.3 oz
Spangdahlem	82/05	F-4E	AFE	Sparrow Hawk	8 oz
Torrejon	82/05	F-4D	AFE	Sparrow	.8 oz
Torrejon	82/10	F-4D	AFE	Wood Pigeon	17.5 oz
Torrejon	82/11	F-4D	AFE	Sparrow	.8 oz
Unknown	83/01	F-4	AFE	Pigeon	10.5 oz

DATA FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES

TABLE 8.4 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-111 CONUS

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Nellis	75/04	F-111A	TAC	Swallow	.5 oz
Mt. Home	76/01	F-111F	TAC	Townsends Warbler	.5 oz
Mt. Home	78/08	F-111A	TAC	Owl	2 - 4 lbs
Unknown	78/10	F-111D	TAC	Cokoo	12 - 16 oz
Cannon	78/10	F-111D	TAC	Lark	1.25 - 1.5 oz
Mt. Home	78/10	F-111A	TAC	Wren	.3 oz
Cannon	78/11	F-111D	TAC	Lark	1.25 - 1.5 oz
Unknown	79/07	F-111D	TAC	Owl	2-4 lbs
Cannon	79/10	F-111	TAC	Cooper's Hawk	2.5 lbs
Unknown	79/11	F-111A	TAC	Red Winged Blackbird	3.3 oz
Mt. Home	81/12	F-111A	TAC	Rock Dove	10 oz
Mt. Home	82/04	EF-111A	TAC	Golden Eagle	9.5 lbs
Mt. Home	82/08	F-111A	TAC	Golden Eagle	9.5 lbs
Mt. Home	82/10	F-111A	TAC	Horned Lark	1.25 - 1.5 oz

DATA FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES

TABLE 8.5 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

F-111 EUROPE

BASE	STRIKE DATE	A/C	COMMAND	BIRD TYPE	BIRD WEIGHT
Upper Heyford RAF	76/04	F-111E	AFE	Seagull	8 oz
Lakenheath RAF	78/09	F-111F	AFE	Robin	3 oz
Lakenheath RAF	79/07	F-111F	AFE	Blackhead Seagull	8 oz
Lakenheath RAF	80/07	F-111F	AFE	Herring Gull	2 1/2 lb
Lakenheath RAF	80/10	F-111F	AFE	Lapwing	8 oz
Incirlik	80/12	F-111E	AFE	Rock Dove	10 oz
Incirlik	81/01	F-111F	AFE	Hood Crow	8 oz
Incirlik	81/01	F-111F	AFE	Rock Dove	10 oz
Incirlik	81/02	F-111F	AFE	Chough	9.5 - 13 oz
Upper Heyford RAF	81/10	F-111	AFE	Turkey Buzzard	2.5 lbs
Lakenheath RAF	82/06	F-111F	AFE	Seagull	8 oz
Upper Heyford RAF	82/10	F-111E	AFE	Lapwing	8 oz
Incirlik	82/10	F-111E	AFE	Shorelark	1.25 - 1.5 oz
Lakenheath RAF	82/10	F-111F	AFE	Turkey Buzzard	2.5 lbs
Lakenheath RAF	82/10	F-111F	AFE	Turkey Buzzard	2.5 lbs
Upper Heyford RAF	82/09	F-111E	AFE	Raven	8 oz

DATA FROM BASH TEAM, TYNDALL AFB, COMPUTER FILES

TABLE 8.6 LIST OF IDENTIFIED BIRDS INVOLVED IN BIRD STRIKE

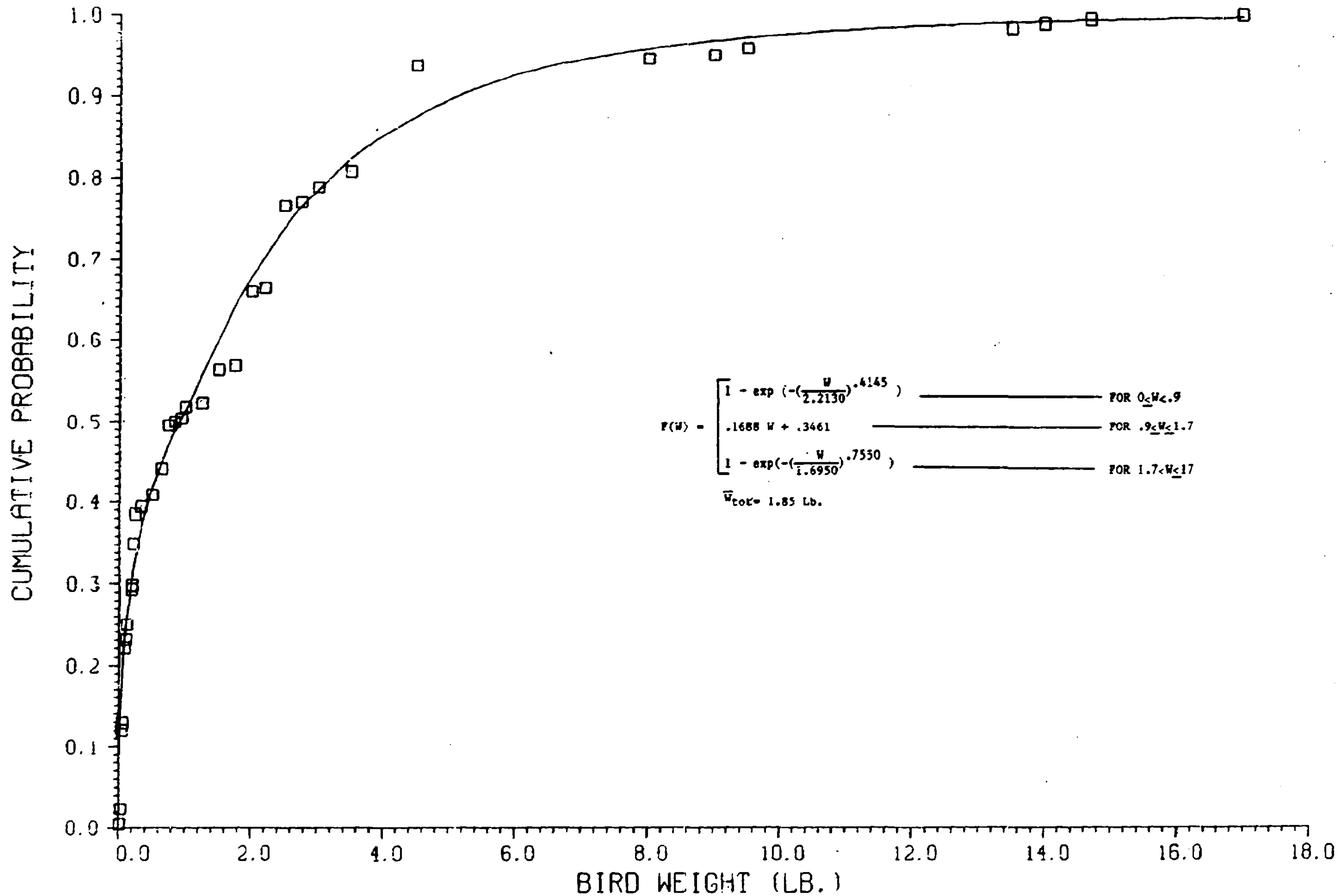


FIG. 6 CONUS BIRD WEIGHT DISTRIBUTION
BIRD WEIGHT DATA FROM BASH TEAM COMPUTER FILES

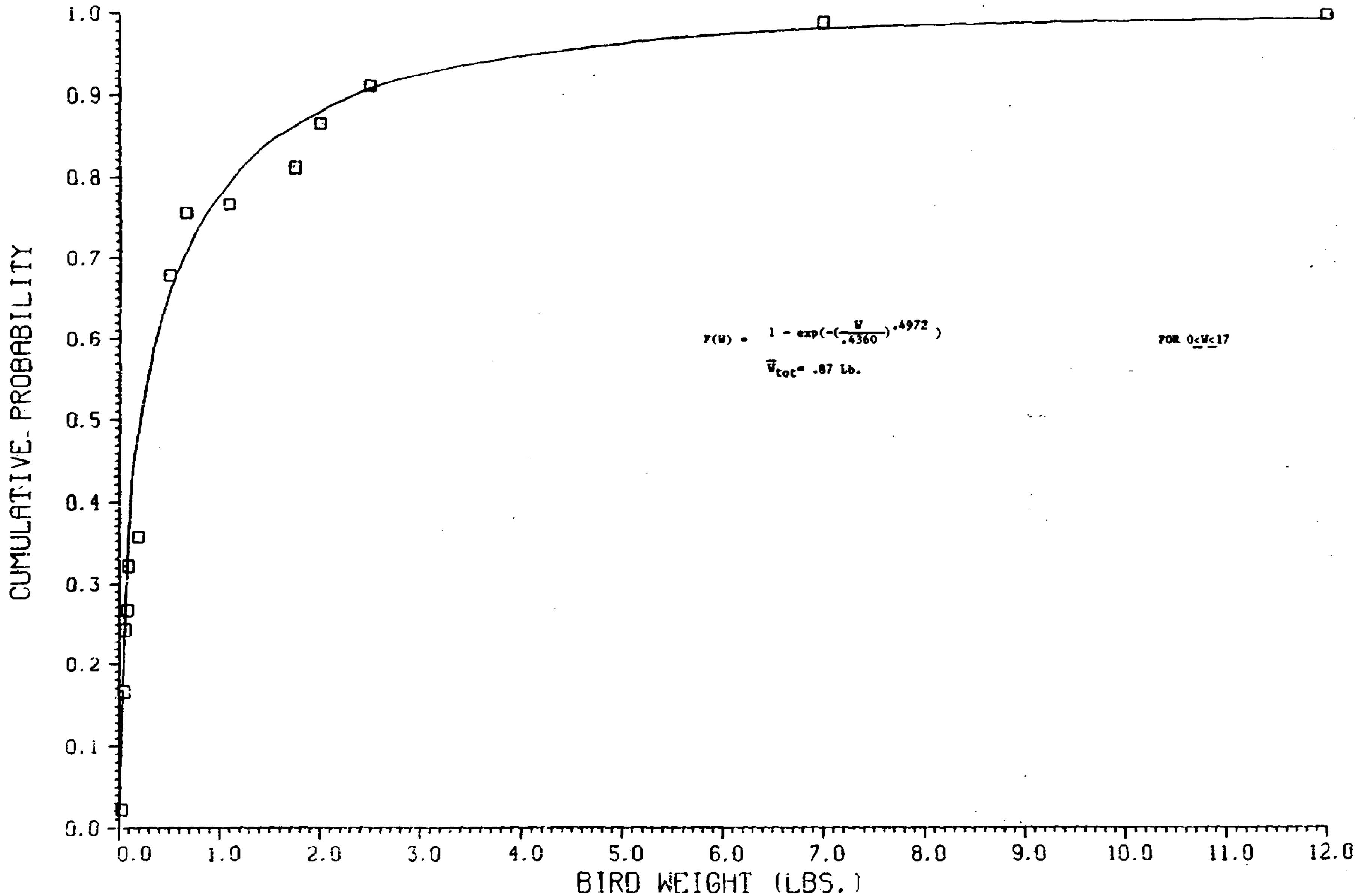


FIG. 7 EUROPE BIRD WEIGHT DISTRIBUTION
BIRD WEIGHT DATA FROM BASH TEAM COMPUTER FILES

COMPONENT STRENGTH DISTRIBUTIONS

The canopy and windshield strength distributions are the percent area of the component which would be damaged, expressed as a function of impact kinetic energy. Since the majority of USAF bird impact testing is done with an equivalent of a 4 lb bird, the strength distributions have been derived based on the kinetic energy developed by this bird weight.

For example:

$$K.E. = 1/2\ mV^2 \tag{14}$$

so, for the impact by a 4 lb bird at 410 Knots:

$$m = \frac{4}{32.2} = .1242\ \frac{\text{LBS}}{\text{FT/SEC}^2}$$

$$410 \text{ Knots} \times 1.688 = 692.0800 \text{ ft/sec}$$

$$K.E. = 1/2\ (.1242)\ (692.0800)^2$$

$$K.E. = 29{,}744.3305 \text{ FT-LBS}$$

Based on Figure 16 for the above kinetic energy, 100% of the present F-15 windshield is critical, meaning that a penetration would occur anywhere on the windshield by a 4 lb bird. At a velocity of 330 knots, an impact by a 4 lb bird (KE = 19,269.23 FT-LBS) makes the windshield 44% critical (44% chance of penetration occurring). Figure 8 shows the F-15 single and two seat model aircraft windshield and canopy profiles. Figures 9 and 10 define the present component capability in terms of penetration/no penetration.

The present capability for the windshield and canopy was obtained from past F-15 bird impact tests (McDonnell Douglas Report, MDC A4888). Since two bird impact points tested were not the most critical locations on the windshield, T-38 data was used to develop the present capability as shown in figures 9 and 10. The T-38 data was extracted from AFWAL report #TR-80-3132, PART I, and it was used since the T-38 had an exhaustive bird impact test program, as well as the T-38 windshield is geometrically similar and made out of the same material (monolithic stretched acrylic) as the F-15 windshield. Percentage of area was determined by using the T-38 percentage distribution (F-15 capability). Figure 15 shows the T-38 penetration values by a 4 lb bird as obtained from the bird impact test program. Using similar ratios, the F-15 capability was obtained and is summarized in Figures 9 and 10.

Example calculation:

From F-15 birdstrike test on windshield, no penetration occurred at 393 kts (severe cracking); at 431 kts, penetration occurred (center impact).

Therefore, 431-393 = 38 KTS

$\frac{38}{2} = 19$ $\qquad$ $393 + 19 = 412 \simeq 410$ KTS

410 kts represents the predicted penetration value since severe cracking occured at 393 KTS.

$\simeq$ 390 KTS represents no penetration by a 4 lb bird

$\simeq$ 410 KTS represents penetration by 4 lb bird

* Δ of 20 KTS from severe cracking to penetration.

Further, additional areas were assessed as follows:

From Fig. 15

320 - 210 = 110 KTS (Δ)

320 - 230 = 90 KTS (Δ).

For F-15 same areas,

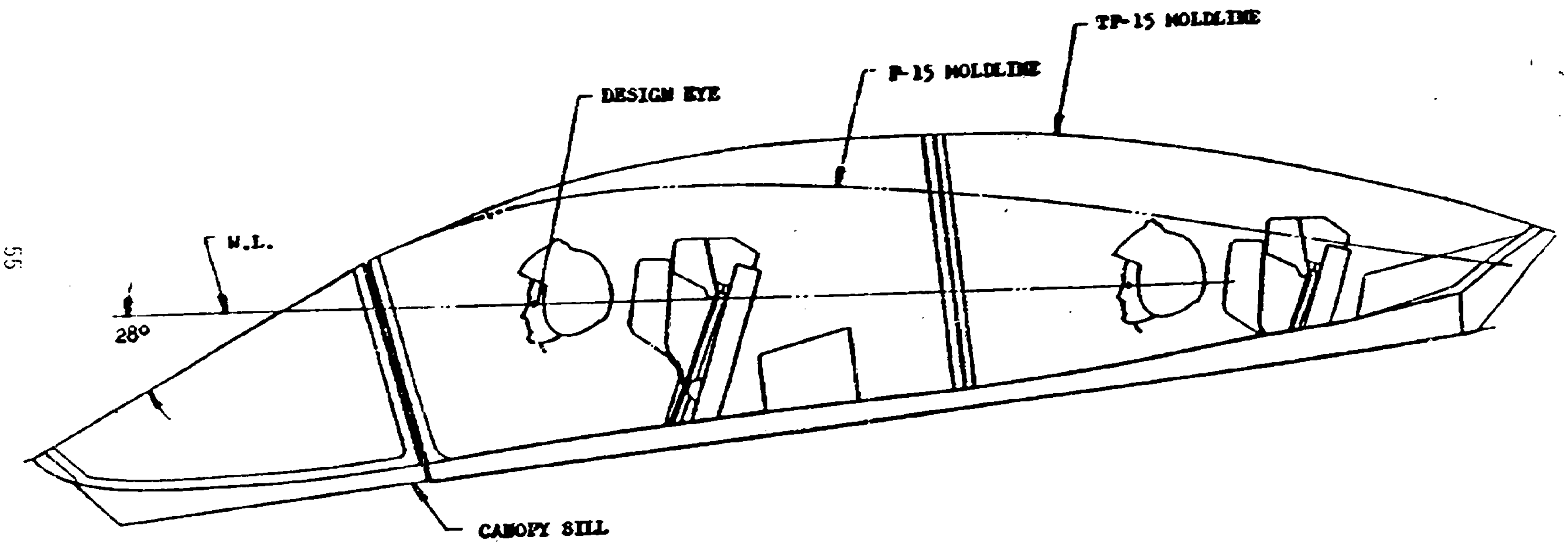
410 - 110 = 300 KTS

410 - 90 = 320 KTS.

Results summarized in figure 10.

For the F-15 canopy only one point was tested, near the canopy arch. At 160 KTS, no penetration occurred, and at 182 KTS, penetration did occur. The transition zone was estimated from 180 to 450 using T-38 percentage areas from Reference 2. The T-38 canopy value of 125 KTS was represented for the F-15 by a range from 180 - 450 KTS, since the F-15 canopy is thicker than the T-38 and it was not felt that decreasing capability exists for the F-15 as it does for the T-38. The zone for the T-38 that is represented by 125 KTS could have easily been a bad shot. Therefore, the F-15 transition zones were estimated as shown in Figure 16. The plotted values were bird penetration values from Figure 10. Similar methods were used to extrapolate increased windshield and canopy capabilities, and these are summarized in Figures 11 - 14. Increased capability component strength distributions are summarized in Figures 17 and 18.

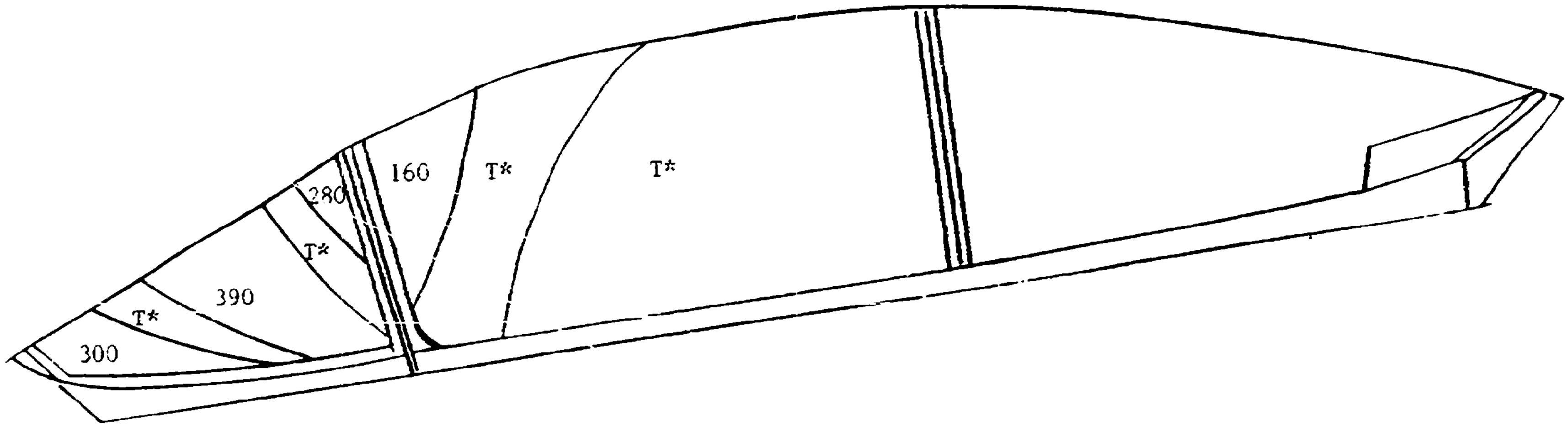
The above approach was recommended by Mr Blaine West from University of Dayton Research Institute, since it was representative of realistic component capability. The above component strength capabilities were estimated using the above estimation process.



F = SINGLE SEAT F-15

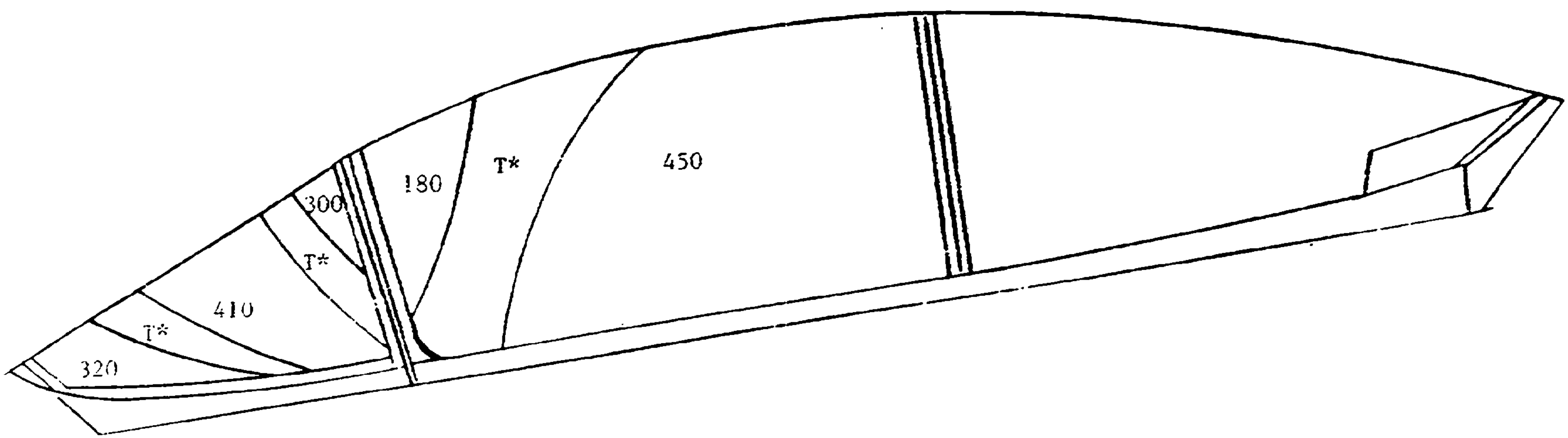
TF = 2 SEAT F-15

FIGURE 8 PROFILE OF F-15F AND TF WINDSHIELD AND CANOPY



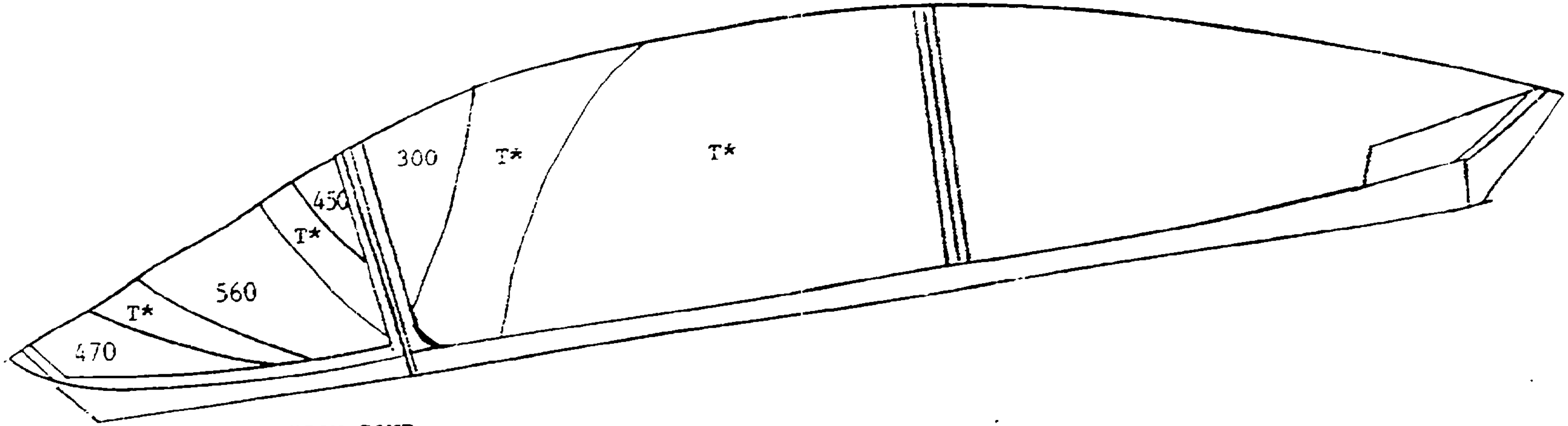
*TRANSITION ZONE
IMPACT VELOCITY KNOTS

FIGURE 9 EXISTING F-15 TRANSPARENCY CAPABILITY
(NO PENETRATION BY A 4 LB BIRD)



*TRANSITION ZONE
IMPACT VELOCITY KNOTS

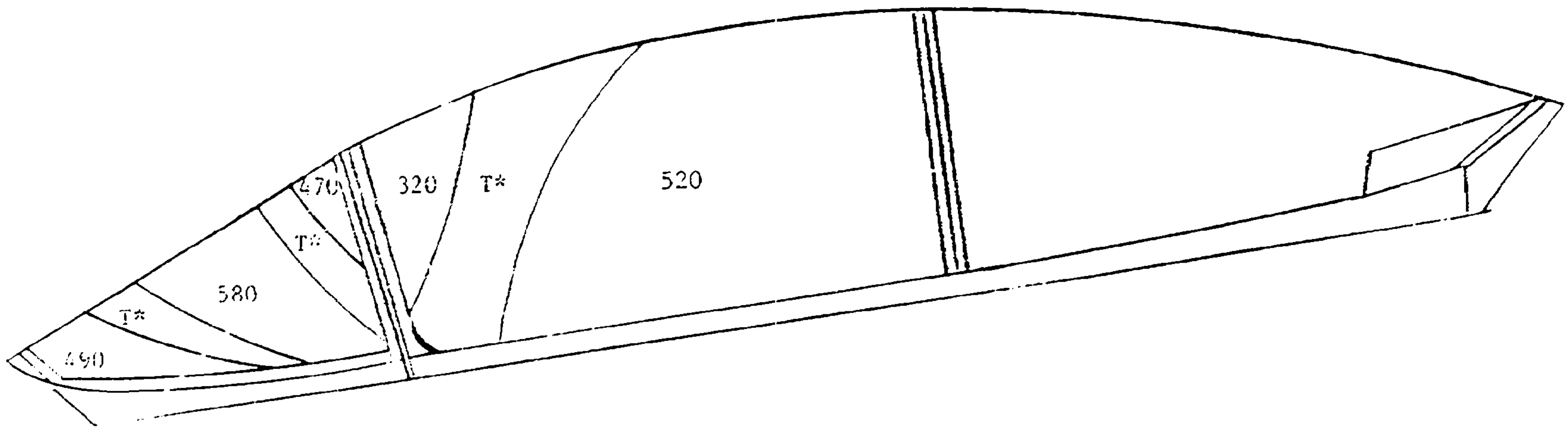
FIGURE 10 EXISTING F-15 TRANSPARENCY PENETRATION VALUES BY A 4 LB BIRD



*TRANSITION ZONE
IMPACT VELOCITY KNOTS

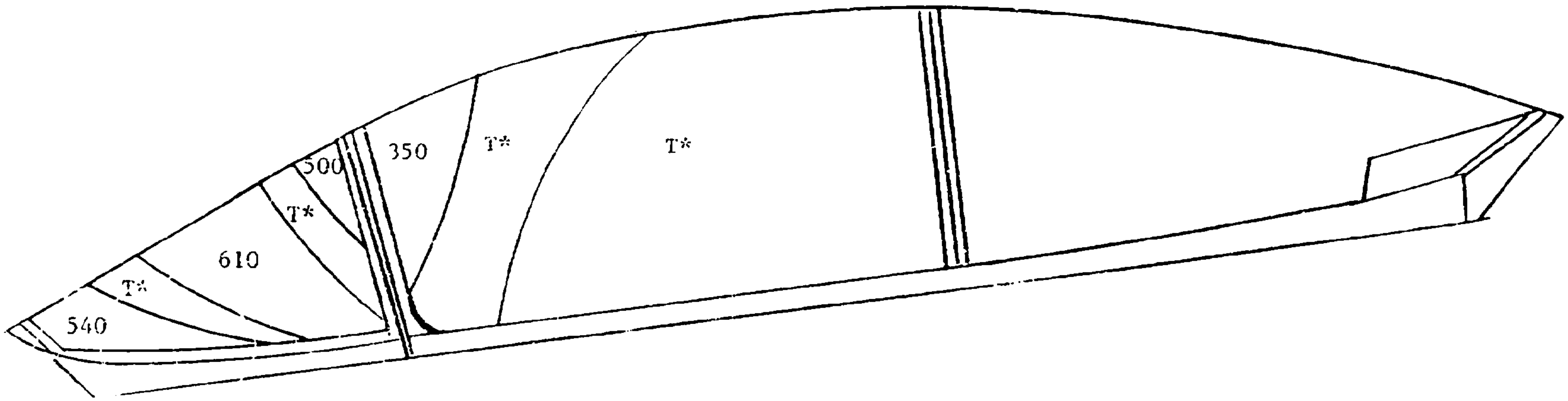
FIGURE 11 450 KT WINDSHIELD/300 KT CANOPY CAPABILITY

(NO PENETRATION BY A 4 LB BIRD)



*TRANSITION ZONE
IMPACT VELOCITY KNOTS

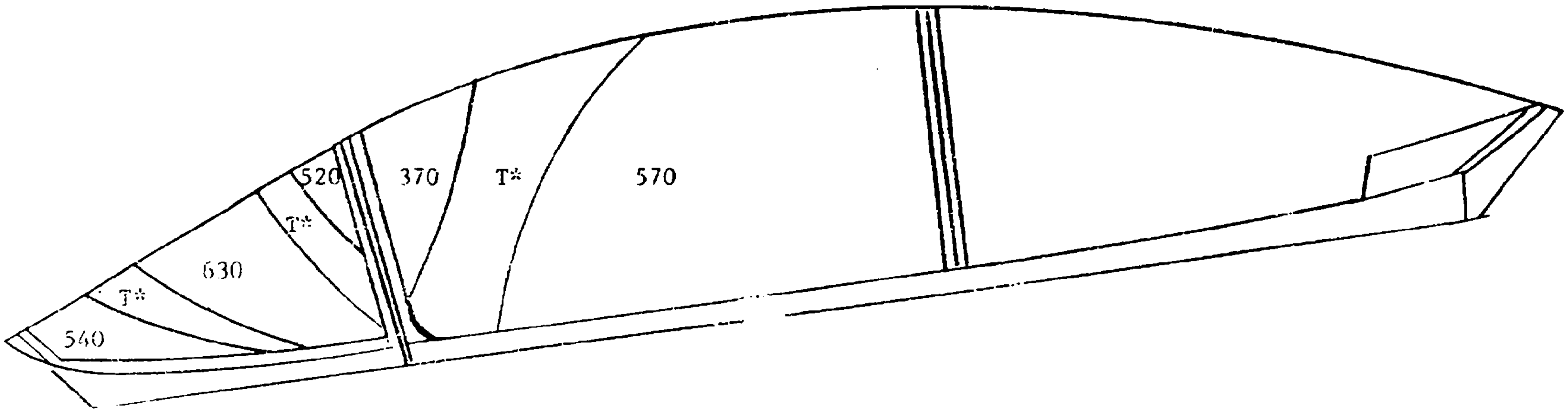
FIGURE 1[illegible] 450 KT WINDSHIELD/300 KT CANOPY CAPABILITY PENETRATION VALUES BY A 4 LB BIRD



*TRANSITION ZONE
IMPACT VELOCITY KNOTS

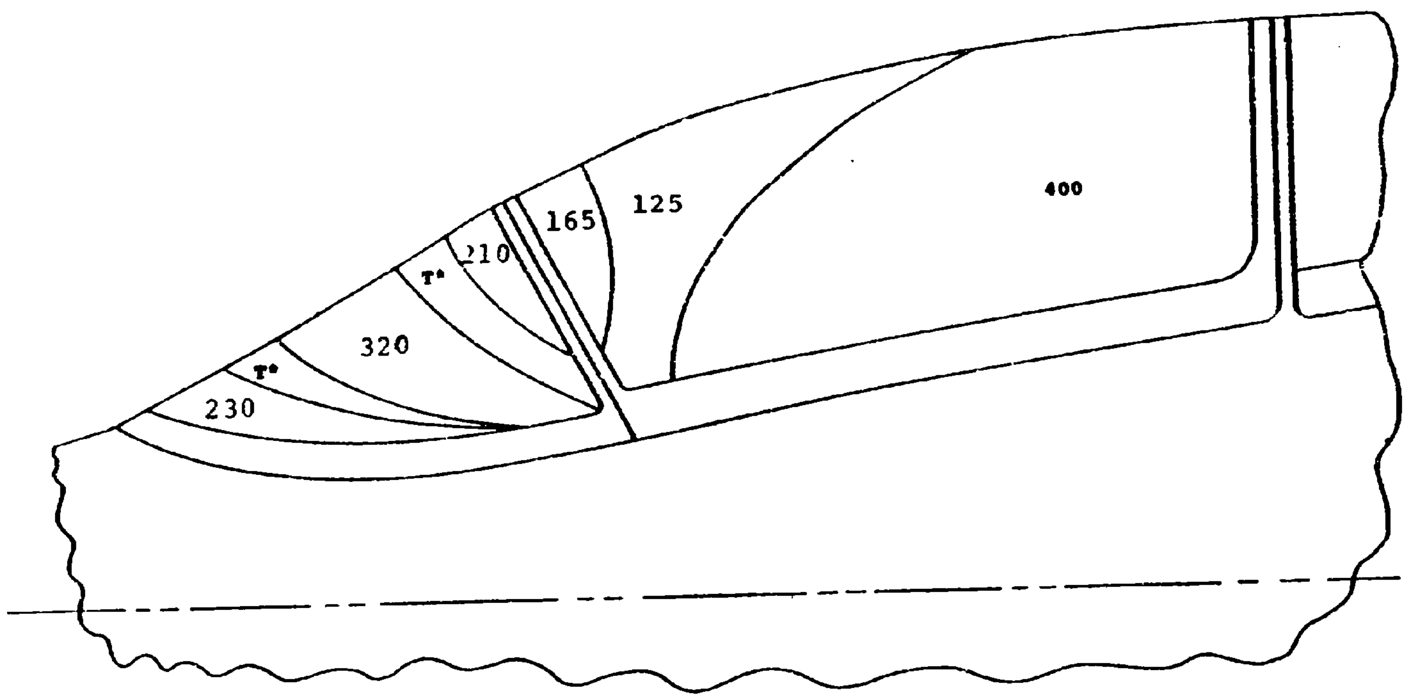
FIGURE 13 500 KT WINDSHIELD/350 KT CANOPY CAPABILITY

(NO PENETRATION BY A 4 LB BIRD)



*TRANSITION ZONE
IMPACT VELOCITY KNOTS

FIGURE 14 500 KT WINDSHIELD/350 KT CANOPY CAPABILITY PENETRATION VALUES BY A 4 LB BIRD



* Transition Zone
Impact Velocity in Knots

FROM AFWAL REPORT #TR-80-3132, PART I

FIGURE 15 EXISTING T-38 TRANSPARENCY PENETRATION VALUES BY A 4 LB BIRD

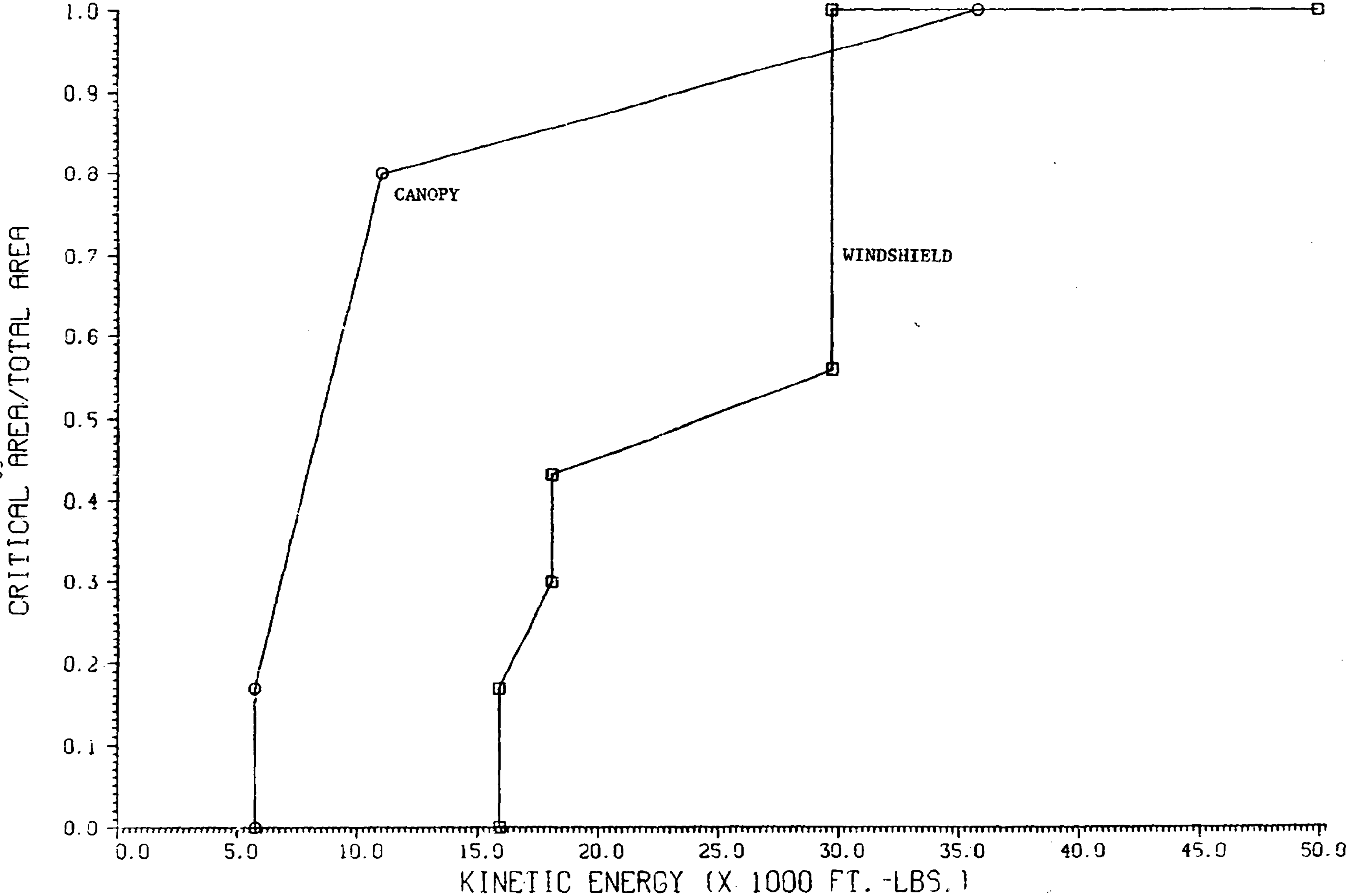


FIG. 16 CRITICAL AREA DISTRIBUTION
F-15 PRESENT WINDSHIELD AND CANOPY CAPABILITY

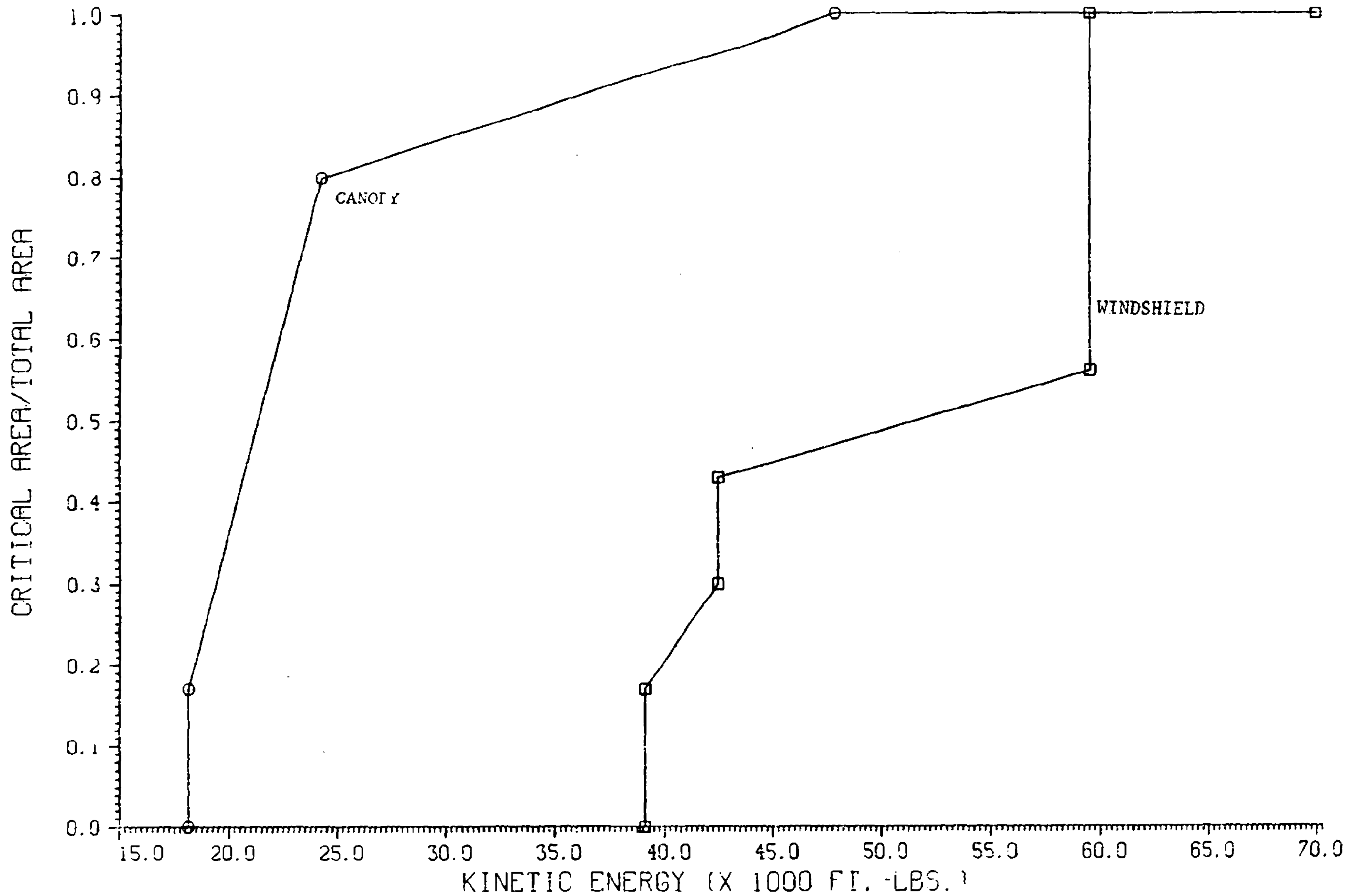


FIG. 17 CRITICAL AREA DISTRIBUTION
INCREASED CAPABILITY, 450 KT. WINDSHIELD AND 300 KT. CANOPY

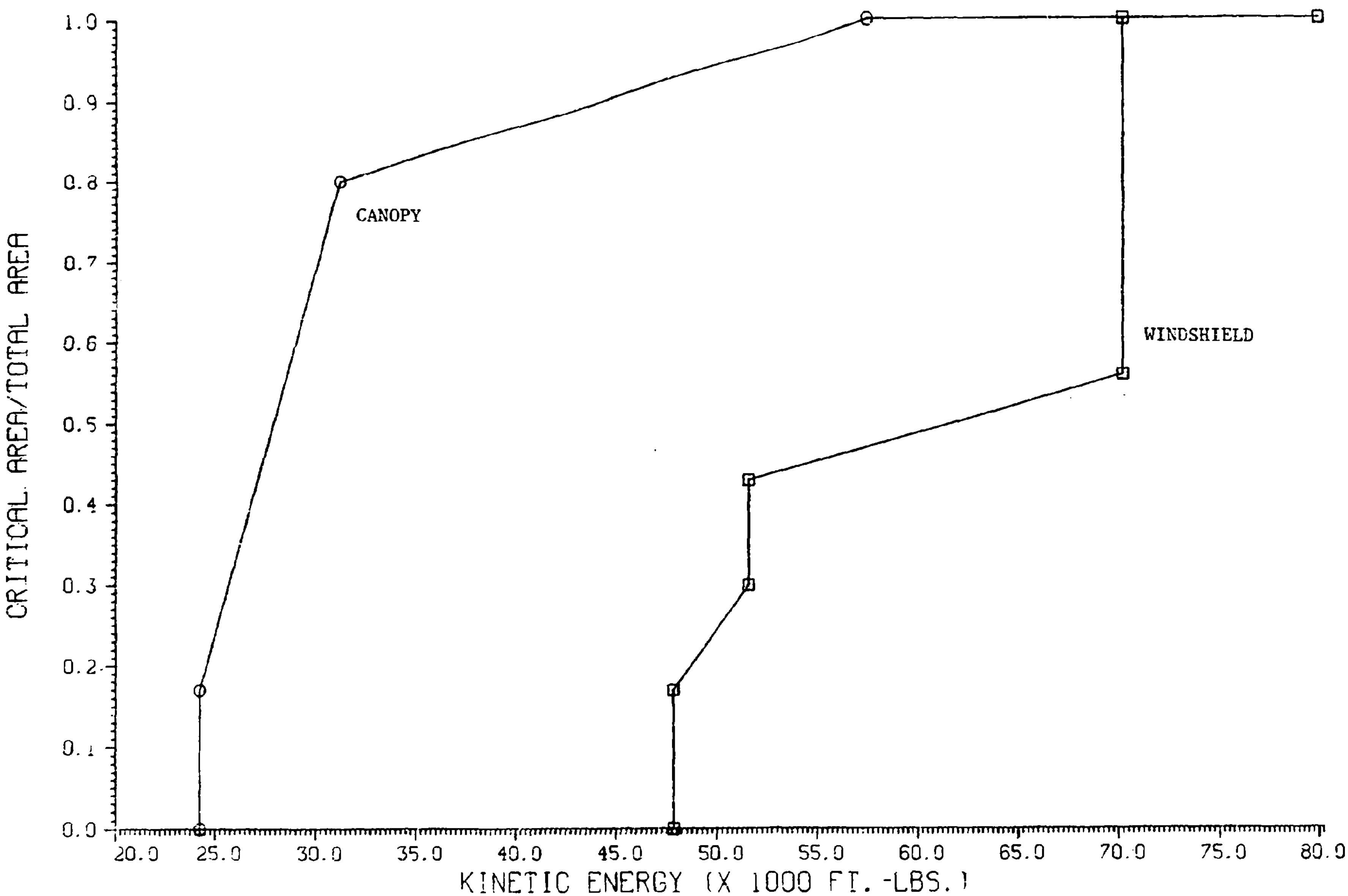


FIG. 18 CRITICAL AREA DISTRIBUTION
INCREASED CAPABILITY, 500 KT. WINDSHIELD AND 350 KT. CANOPY

MODEL APPLICATION

Since all inputs have been already derived, the number of penetrations on a specific component, windshield or canopy, can be obtained by the product of:

#PENETRATIONS = OIR X FORCE USAGE X $\Delta P(V)$ X $\Delta P(W)$ X CRITICAL AREA

OIR = OPERATIONAL IMPACT RATE PER 10^6 HRS (15)

FORCE USAGE = TOTAL Flight Hours for specific mission air-to-air or air-to-ground

$\Delta P(V)$ = aircraft velocity probability
$\Delta P(W)$ = bird weight probability
Critical area = Windshield or canopy area capability

$\Delta P(V)$ and $\Delta P(W)$ values are obtained by evaluating the respective cumulative probability distribution function for a desired range (Table 9.0 - 9.6). The critical area values are obtained first by developing a kinetic energy matrix (Table 10.0).

Eqn 14 is used to determine each element of the matrix.

Example:

For velocity range 310 -360 → Nominal 335 KTS and bird weight

4 - 5 → Nominal 4.5 LBS

$KE = 1/2\ m\ V^2$

KE = 22,344 Ft Lbs

For velocity range 160 - 210 → Nominal 185 KTS and bird weight

1 - 2 → Nominal 1.5 Lbs

KE = 2271 Ft Lbs

From Table 10.0 for each kinetic energy value (each element), figures 16 - 18 are used to obtain proportion of component critical area. Table 10.1 and 10.2 lists the results in the 12 by 15 matrix, for the present capability windshield and canopy. The use of eqn 15 obtains the number of penetrations that exceed the kinetic energy of the specific subsystem. A summation is then taken of all incremental bird penetration values from the 12 by 15 matrix, and a total number of penetrations for a specific usage profile is obtained.

AIR/AIR + INST/NAV + All Missions Flown (except AIR TO GROUND)

CONUS & EUROPE

CUM. PROB	VELOCITY (KTS)	VELOCITY (KTS)	$\Delta P(V)$
.0001	116	110 - 160	.0948
.0949	160	160 - 210	.1501
.2450	210	210 - 260	.1950
.4400	260	260 - 310	.2040
.6440	310	310 - 360	.1660
.8100	360	360 - 410	.1080
.9180	410	410 - 460	.0540
.9720	460	460 - 510	.0210
.9930	510	510 - 560	.0060
.9990	560	560 - 610	.0010
1.0000	610	610 - 660	0
1.0000	660	660 - 710	0
1.0000	710		

$$F(V) = \begin{cases} -5.793168 + 2.49687\times10^{-1}\, V - 4.296046\times10^{-3}\, V^2 + 3.774985\times10^{-5}\, V^3 - 1.792476\times10^{-7}\, V^4 + 4.396387\times10^{-10}\, V^5 - 4.371569\times10^{-13}\, V^6 & \text{FOR } 116 \le V \le 200 \\ 1 - \exp\left(-\left(\frac{V-40}{307-40}\right)^{2.81}\right) & \text{FOR } 200 < V \le 720 \end{cases}$$

$\overline{V}_{tot} = 279.24$ Knots

TABLE 9.0 F-15 PRESENT FLEET

AIR TO GROUND MISSION

CONUS & EUROPE

CUM PROB	VELOCITY (KTS)	VELOCITY (KTS)	ΔP(V)
.0002	110	110 - 160	.0217
.0219	160	160 - 210	.0257
.0476	210	210 - 260	.0111
.0587	260	260 - 310	.0102
.0689	310	310 - 360	.0626
.1315	360	360 - 410	.1905
.3220	410	410 - 460	.3040
.6260	460	460 - 410	.2540
.8880	510	510 - 560	.1000
.9880	560	560 - 610	.0120
1.0000	610		

$$F(V) = \begin{cases} -4.276016\text{X}10^{-2} + 2.515055\text{X}10^{-3}\,V - 5.176007\text{X}10^{-5}\,V^2 + 4.649071\text{X}10^{-7}\,V^3 - 1.908740\text{X}10^{-9}\,V^4 + 3.569492\text{X}10^{-12}\,V^5 - 2.406103\text{X}10^{-15}\,V^6 & \text{FOR } 110 \le V \le 380 \\ 1 - \exp\left(-\left(\frac{V - 110}{461-110}\right)^{6.01}\right) & \text{FOR } 380 < V \le 610 \end{cases}$$

$\overline{V}_{tot}$ = 427.90 Knots

TABLE 9.1 F-15 RAPID DEPLOYMENT FORCE

AIR TO AIR + INST/NAV + All Missions Flown (except AIR TO GROUND)

CONUS & EUROPE

CUM PROB	VELOCITY (KTS)	VELOCITY (KTS)	Δ P(V)
.0001	116	110 - 160	.0948
.0949	160	160 - 210	.1501
.2450	210	210 - 260	.1950
.4400	260	260 - 310	.2040
.6440	310	310 - 360	.1660
.8100	360	360 - 410	.1080
.9180	410	410 - 460	.0540
.9720	460	460 - 510	.0210
.9930	510	510 - 560	.0060
.9990	560	560 - 610	.0010
1.0000	610	610 - 660	.0000
1.0000	660	660 - 710	.0000
1.0000	710		

$$F(V) = \begin{cases} -5.793168 + 2.49687\times10^{-1}\,V - 4.296046\times10^{-3}\,V^2 \\ +3.774985\times10^{-5}\,V^3 - 1.792476\times10^{-7}\,V^4 \\ +4.396387\times10^{-10}\,V^5 - 4.371569\times10^{-13}\,V^6 & \text{FOR } 116 \le V \le 200 \\ 1 - \exp\left(-\left(\frac{V-40}{307-40}\right)^{2.81}\right) & \text{FOR } 200 < V \le 720 \end{cases}$$

$\overline{V}_{tot} = 279.24$ Knots

TABLE 9.2 F-15 RAPID DEPLOYMENT FORCE

AIR TO AIR + INST/NAV + All Missions Flown (except AIR TO GROUND)

CONUS & EUROPE

CUM PROB	VELOCITY (KTS)	VELOCITY (KTS)	$\Delta P(V)$
.0001	116	110 - 160	.0948
.0949	160	160 - 210	.1501
.2450	210	210 - 260	.1950
.4400	260	260 - 310	.2040
.6440	310	310 - 360	.1660
.8100	360	360 - 410	.1080
.9180	410	410 - 460	.0540
.9720	460	460 - 510	.0210
.9930	510	510 - 560	.0060
.9990	560	560 - 610	.0010
1.0000	610	610 - 660	.0000
1.0000	660	660 - 710	.0000
1.0000	710		

$$F(V) = \begin{cases} -5.793168 + 2.49687\times10^{-1}\,V - 4.296046\times10^{-3}\,V^2 \\ +3.774985\times10^{-5}\,V^3 - 1.792476\times10^{-7}\,V^4 \\ +4.396387\times10^{-10}\,V^5 - 4.371569\times10^{-13}\,V^6 & \text{FOR } 116\le V\le 200 \\ 1 - \exp\left(-\left(\frac{V-40}{307-40}\right)^{2.81}\right) & \text{FOR } 200< V\le 720 \end{cases}$$

$\overline{V}_{tot} = 279.24$ Knots

TABLE 9.3 F-15 DUAL ROLE FIGHTER

AIR TO GROUND MISSION

CONUS & EUROPE

CUM PROB	VELOCITY (KTS)	VELOCITY (KTS)	$\Delta P(V)$
.0032	110	110 - 160	.0431
.0463	160	160 - 210	.0159
.0522	210	210 - 260	.0153
.0775	260	260 - 310	.0195
.0970	310	310 - 360	.0125
.1095	360	360 - 410	.0375
.1470	410	410 - 460	.2470
.3940	460	460 - 410	.4390
.8330	510	510 - 560	.1630
.9960	560	560 - 610	.0040
1.0000	610		

$$F(V) = \begin{cases} +8.284557\times10^{-5} - 5.55111\times10^{-3}\,V + 1.172276\times10^{-4}\,V^2 \\ -9.165418\times10^{-7}\,V^3 + 3.493164\times10^{-9}\,V^4 \\ -6.493033\times10^{-12}\,V^5 + 4.716360\times10^{-15}\,V^6 & \text{FOR } 110\le V\le 440 \\ 1 - \exp\left(-\left(\frac{V-110}{486.3-110}\right)^{9.5321}\right) & \text{FOR } 440< V\le 620 \end{cases}$$

$\overline{V}_{tot} = 445.91$ Knots

TABLE 9.4 F-15 DUAL ROLE FIGHTER

CONUS

WEIGHT (LBS)	Δ P(W)	CUM. PROB	WEIGHT (LBS)
0 - 1	.5149	0	0
1 - 2	.1631	.5149	1
2 - 3	.1074	.6780	2
3 - 4	.0668	.7854	3
4 - 5	.0438	.8522	4
5 - 6	.0295	.8960	5
6 - 7	.0204	.9255	6
7 - 8	.0144	.9459	7
8 - 9	.0103	.9603	8
9 - 10	.0075	.9706	9
10 - 11	.0054	.9781	10
11 - 12	.0040	.9835	11
12 - 13	.0030	.9875	12
13 - 14	.0022	.9905	13
14 - 15	.0017	.9927	14
		.9944	15

$$F(W) = \begin{cases} 1 - \exp\left(-\left(\frac{W}{2.2130}\right)^{.4145}\right) & \text{FOR } 0 \leq W < .9 \\ .1688\,W + .3461 & \text{FOR } .9 \leq W \leq 1.7 \\ 1 - \exp\left(-\left(\frac{W}{1.6950}\right)^{.7550}\right) & \text{FOR } 1.7 < W \leq 17 \end{cases}$$

$\overline{W}_{tot}$ = 1.85 Lb.

TABLE 9.5 BIRD WEIGHT DISTRIBUTION

EUROPE

WEIGHT (LBS)	$\Delta P(W)$	CUM. PROB	WEIGHT (LBS)
0 - 1	.7793	0	0
1 - 2	.1022	.7793	1
2 - 3	.0449	.8815	2
3 - 4	.0243	.9264	3
4 - 5	.0147	.9507	4
5 - 6	.0094	.9654	5
6 - 7	.0064	.9748	6
7 - 8	.0045	.9812	7
8 - 9	.0032	.9857	8
9 - 10	.0024	.9889	9
10 - 11	.0018	.9913	10
11 - 12	.0014	.9931	11
12 - 13	.0010	.9945	12
13 - 14	.0008	.9955	13
14 - 15	.0007	.9963	14
		.9970	15

$$F(W) = 1 - \exp\left(-\left(\frac{W}{.4360}\right)^{.4972}\right) \qquad \text{FOR } 0 \leq W \leq 17$$

$\overline{W}_{tot} = .87$ Lb.

TABLE 9.6 BIRD WEIGHT DISTRIBUTION

KINETIC ENERGY (FT-LBS X 1000)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	403.	1210.	2016.	2822.	3629.	4435.	5241.	6048.	6854.	7660.	8467.	9273.	10079.	10886.	11692.
160-210	757.	2271.	3786.	5300.	6814.	8328.	9843.	11357.	12871.	14386.	15900.	17414.	18928.	20443.	21957.
210-260	1222.	3665.	6109.	8552.	10995.	13439.	15882.	18326.	20769.	23212.	25656.	28099.	30543.	32986.	35429.
260-310	1797.	5391.	8984.	12578.	16172.	19766.	23359.	26953.	30547.	34141.	37734.	41328.	44922.	48516.	52109.
310-360	2483.	7448.	12413.	17379.	22344.	27309.	32275.	37240.	42205.	47171.	52136.	57101.	62067.	67032.	71997.
360-410	3279.	9837.	16395.	22953.	29512.	36070.	42628.	49186.	55744.	62302.	68860.	75419.	81977.	88535.	95093.
410-460	4186.	12558.	20930.	29303.	37675.	46047.	54419.	62791.	71163.	79536.	87908.	96280.	104652.	113024.	121396.
460-510	5204.	15611.	26019.	36426.	46833.	57241.	67648.	78056.	88463.	98870.	109278.	119685.	130093.	140500.	150907.
510-560	6312.	18996.	31660.	44324.	56987.	69651.	82315.	94979.	107643.	120307.	132971.	145635.	158298.	170962.	183626.
560-610	7571.	22717.	37854.	52995.	68137.	83279.	98420.	113562.	128703.	143845.	158986.	174128.	189270.	204411.	219553.
610-660	8920.	26761.	44601.	62442.	80282.	98123.	115963.	133804.	151644.	169485.	187325.	205165.	223006.	240846.	258687.
660-710	10380.	31141.	51902.	72662.	93423.	114183.	134944.	155705.	176465.	197226.	217986.	238747.	259508.	270268.	301029.

TABLE 10.0 KINETIC ENERGY MATRIX

CRITICAL AREA/TOTAL AREA

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
110-160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160-210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210-260	0	0	0	0	0	0	0	0	0	0	0	.258	.439	.456	.473
260-310	0	0	0	0	0	0	0	.432	.459	.487	.514	.542	1.0	1.0	1.0
310-360	0	0	0	0	.184	.448	.488	.529	1.0	1.0	1.0	1.0	1.0	1.0	1.0
360-410	0	0	0	.256	.477	.533	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
410-460	0	0	.198	.484	.557	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
460-510	0	0	.461	.555	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
510-560	0	0	.518	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
560-610	0	.440	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
610-660	0	.481	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
660-710	0	.527	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 10.1 WINDSHIELD CRITICAL AREA/TOTAL AREA, PRESENT CAPABILITY

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
110-160	0	0	0	0	0	0	0	.207	.302	.398	.493	.588	.684	.779	.805
160-210	0	0	0	0	.298	.477	.656	.802	.814	.826	.839	.851	.863	.875	.888
210-260	0	0	.214	.503	.792	.819	.838	.858	.878	.898	.918	.937	.957	.977	.997
260-310	0	0	.554	.812	.841	.870	.899	.928	.957	.986	1.0	1.0	1.0	1.0	1.0
310-360	0	.373	.810	.851	.891	.931	.971	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0
360-410	0	.655	.843	.896	.949	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
410-460	0	.812	.879	.947	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
460-510	0	.836	.921	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
510-560	.241	.864	.966	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
560-610	.387	.894	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
610-660	.547	.927	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
660-710	.719	.962	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 10.2 CANOPY CRITICAL AREA/TOTAL AREA, PRESENT CAPABILITY

USE OF COMPUTER PROGRAM FOR MODEL APPLICATION

Appendix A lists an interactive computer program which was used to obtain the number of bird penetrations for each component varying t_H. Program BAAPF evaluates the present fleet air-to-air mission. The inputs for the program are in line number 140 - 740 and can be changed to evaluate the RPD and DRF air-to-air/air-to-ground missions. In the above program lines, the following are input parameters:

(140) PWC - Δ P(W) bird weight probability for CONUS. From Table 9.5 (Does not change when evaluating F-15 Present Fleet, F-15 RPD, F-15 DRF).

(160) PWE - Δ P(W) bird weight probability for Europe. From Table 9.6 (Does not change when evaluating F-15 Present Fleet, F-15 RPD, F-15 DRF).

(230) PVI - Δ P(V) velocity probability. From Table 9.0 - 9.5 (changes for air-to-air and air-to-ground missions)

(250 - 740) Windshield and Canopy Critical area Proportions. From Table 10.1 and 10.2 for present Windshield and Canopy Capability. (These values change for increased capability. By using Figures 17 and 18, a similar Table to 10.1 and 10.2 can be obtained).

Appendix B contains the results, after running the program BAAPF, for the F-15 present fleet (air-to-air mission). The first matrix, expected number of birdstrikes (uncorrected), is not corrected for critical area. The second matrix, expected number of birdstrikes, is corrected for critical area, and the summation of all elements of this matrix is the total number of penetrations for a specific, component, theatre, OIR, Force Usage, or mission. The Appendix C program lists only the results, the total number of bird penetrations.

EVALUATION OF RESULTS

To date, the F-15 fleet has had one bird penetration on the windshield, and two incidents resulting in two cracked windshields and one cracked canopy. Of these two incidents, no penetration into the cockpit has occurred. Table 11 summarizes the results of this model's simulation of the F-15 present fleet based on the number of hours flown to date in Conus and Europe and on the present windshield/canopy capability. It is important to note that any value other than an integer value for a penetration is meaningless; however, since this simulation is a numerical solution, fractional values will occur. For example, for Conus, the model predicts 0.45 bird penetrations on the canopy and to date there have been none. Since this is a numerical solution, one can imagine a counter starting when the F-15 fleet started flying. The 0.45 penetrations implies we have not had a penetration on the canopy to this date, but given more time, we will.

The model simulated past history very well, the same methodology was used to evaluate the F-15 RPD and DRF. The results are presented in Figures 19 - 70 for different missions with varying Ts and force usage (flight hours). A realistic usage profile is summarized in Table 12.0 - 12.7 for the RPD and DRF over a 15 year flying period. These graphs can also be used to evaluate other and possibly more realistic usage profiles.

Evaluation of Table 12.7 indicates that, even with a 500 kt windshield and 350 kt canopy, bird penetrations into the cockpit will still occur; however, there is little that can be done to prevent an 8 lb bird from penetrating at 480 knots. To dissipate the energy resulting from an impact of such a severe condition could require structural considerations that would interfere with the capability and function of the aircraft, as well as make the design cost prohibitive based on latest state of the art technology in transparency design.

The number of penetrations that are represented in either the tables or the graphs do not imply aircraft losses. Based on McAir's initial analyses of historical data, one out of every three penetrations resulted in an aircraft loss, fatality, or pilot major injury. This ratio was used to assess the results in terms of aircraft losses, fatalities or pilot major injuries. However, one should note that this type of ratio is based on a small data sample and has not been verified against all existing data from which a more realistic ratio might be inferred.

Figures 19 through 70 can be used to predict the number of bird penetrations for a change in T_s if the force usage shown in Tables 12.0, 12.4, and 12.5 remains the same. From Table 12.3, it is found that the F-15 RPD air to ground missions predicts 9.5 windshield bird penetations for a T_s of 0.8056 and the present windshield capability in CONUS. What is the expected number of windshield bird penetrations if the time spent in the bird threat environment is reduced to a T_s of 0.6? First find the right graph, in this case, Figure 27, "F-15 RPD, Present Windshield Capability, CONUS, Air to Ground." Then from Table 12.0, "F-15 RPD Force Usage," the number of flight hours for the CONUS and air to ground case, 141,750 hours, is used in Figure 27. Since Figure 27 doesn't have a line for a T_s of 0.6, the value is interpolated between T_s of 0.5 and 0.7. From the graph:

At	Flight Hours	T_s	Windshield Bird Penetrations (WBP)
	141,750	.5	WBP.5 = 5.6
	141,750	.6	WBP.6 = ?
	141,750	.7	WBP.7 = 8.3

Using a ratio to interpolate

$$\frac{WBP.7 - WBP.6}{T_{s.7} - T_{s.6}} = \frac{WBP.7 - WBP.5}{T_{s.7} - T_{s.5}}$$

Solving for WBP.6

$$WBP.6 = -\left[\left[\left(\frac{8.3 - 5.6}{.7 - .5}\right)(.7 - .6)\right] - 8.3\right]$$

WBP.6 = 6.95 windshield bird penetrations

CONCLUSIONS

A statistical simulation was used to evaluate the F-15 present windshield and canopy capability with respect to the number of bird penetrations into the cockpit. The results of this simulation as applied to the present fleet recreated past history very precisely. Similar methodology was used to evaluate the F-15 RPD and DRF. The results indicate that the model, using the assumptions and parameters of this analysis, predicts that the present windshield and canopy need improvement for the air-to-ground mission of the RPD and DRF.

BIRD PENETRATIONS*

	MODEL SIMULATION		HISTORICAL	
	CONUS	EUROPE	CONUS	EUROPE
Windshield	1.10	0.08	1	0
Canopy	0.45	0.62	0	0
Hours Flown	473008	136576	473008	136576
Ts	.1198	.2307	.1198	.2307

*with present windshield and canopy capability

TABLE 11 F-15 PRESENT FLEET AIR TO AIR MISSION

Number of aircraft available = 150 aircraft

Average number of hours flown per month = 25 hours

The total number of flying hours for 15 years is:

$$15 \text{ years} \times 150 \text{ A/C} \times \frac{25 \text{ hrs}}{\text{month}} \times \frac{12 \text{ months}}{\text{year}} = 675{,}000 \text{ hrs}$$

Aircraft's distribution: 1 - Conus = 70% of aircraft
2 - Europe = 30% of aircraft

The mission mix is: 1 - 30% air to ground (A/G)
2 - 70% air to air (A/A)

Mission mix data obtained from HQ TAC message 221715Z July 1982

For 15 Years of F-15 RPD Force Usage

	Combined	Conus (70%)	Europe (30%)	Ts Conus	Ts Europe
Total hours	675,000	472,500	202,500		
A/G Hours (30%)		141,750	60,750	.8056	.8056
A/A Hours (70%)		330,750	141,750	.1198	.2307

TABLE 12.0 F-15 RPD FORCE USAGE

WINDSHIELD BIRD PENETRATIONS

	Present Capability	450 Knots Capability	500 Knots Capability
Conus	.75	.15	.09
Europe	.08	.016	.009

CANOPY BIRD PENETRATIONS

	Present Capability	300 Knots Capability	350 Knots Capability
Conus	.30	.11	.07
Europe	.65	.19	.05

TABLE 12.2 F-15 RPD AIR TO AIR MISSION

WINDSHIELD BIRD PENETRATIONS

	Present Capability	450 Knots Capability	500 Knots Capability
Conus	9.50	3.20	2.40
Europe	.60	.17	.12

CANOPY BIRD PENETRATIONS

	Present Capability	300 Knots Capability	350 Knots Capability
Conus	2.60	1.40	1.05
Europe	3.50	1.50	1.0

TABLE 12.3 F-15 RPD AIR TO GROUND MISSION

Production schedule obtained from HQ USAF message 082200Z Apr 83

Years of Production	Number of A/C	Cumulative Number of A/C	Flight hours per year
1st	16	16	4,800
2nd	72	88	26,400
3rd	72	160	48,000
4th	72	232	69,600
5th	72	304	91,200
6th	60	364	109,200
7th	36	400	120,000
Total flight hours for the first 7 years:			447,648

Sample Calculation: for the first year:

$$16\ \text{A/C} \times 25\ \frac{\text{flight hours}}{\text{month}} \times 12\ \frac{\text{month}}{\text{year}} = 4800\ \text{flight hours}$$

For the remaining 8 years, the number of flight hours is:

$$400\ \text{A/C} \times 25\ \frac{\text{flight hours}}{\text{month}} \times 12\ \frac{\text{month}}{\text{year}} \times 8\ \text{years} = 960{,}000\ \text{hours}$$

The total flight hours for 15 years is:

$$447{,}648\ \text{hours} + 960{,}000\ \text{hours} = 1{,}407{,}648\ \text{hours}$$

TABLE 12.4 F-15 DRF FORCE USAGE

Aircraft distribution: 1 - Conus = 70% of aircraft
2 - Europe = 30% of aircraft

The mission mix is: 1 - 75% Air to ground (A/G)
2 - 25% Air to air (A/A)

For 15 years of F-15 DRF Force Usage

	Combined	Conus	Europe	Ts Conus	Ts Europe
Total Hours	1,407,648	985,353	422,294		
A/G Hours (75%)		739,015	316,720	.6360	.6360
A/A Hours (25%)		246,338	105,573	.1198	.2307

TABLE 12.5 F-15 DRF FORCE USAGE

WINDSHIELD BIRD PENETRATIONS

	Present Capability	450 Knots Capability	500 Knots Capability
Conus	.55	.10	.06
Europe	.06	.01	0

CANOPY BIRD PENETRATIONS

	Present Capability	300 Knots Capability	350 Knots Capability
Conus	.40	.13	.08
Europe	.80	.25	.15

TABLE 12.6 F-15 DRF AIR TO AIR MISSION

WINDSHIELD BIRD PENETRATION

	Present Capability	450 Knots Capability	500 Knots Capability
Conus	45.5	17.0	10.9
Europe	2.8	.9	.6

CANOPY BIRD PENETRATIONS

	Present Capability	300 Knots Capability	350 Knots Capability
Conus	19.2	10.7	8.9
Europe	25.5	11.5	8.5

TABLE 12.7 F-15 DRF, AIR TO GROUND MISSION

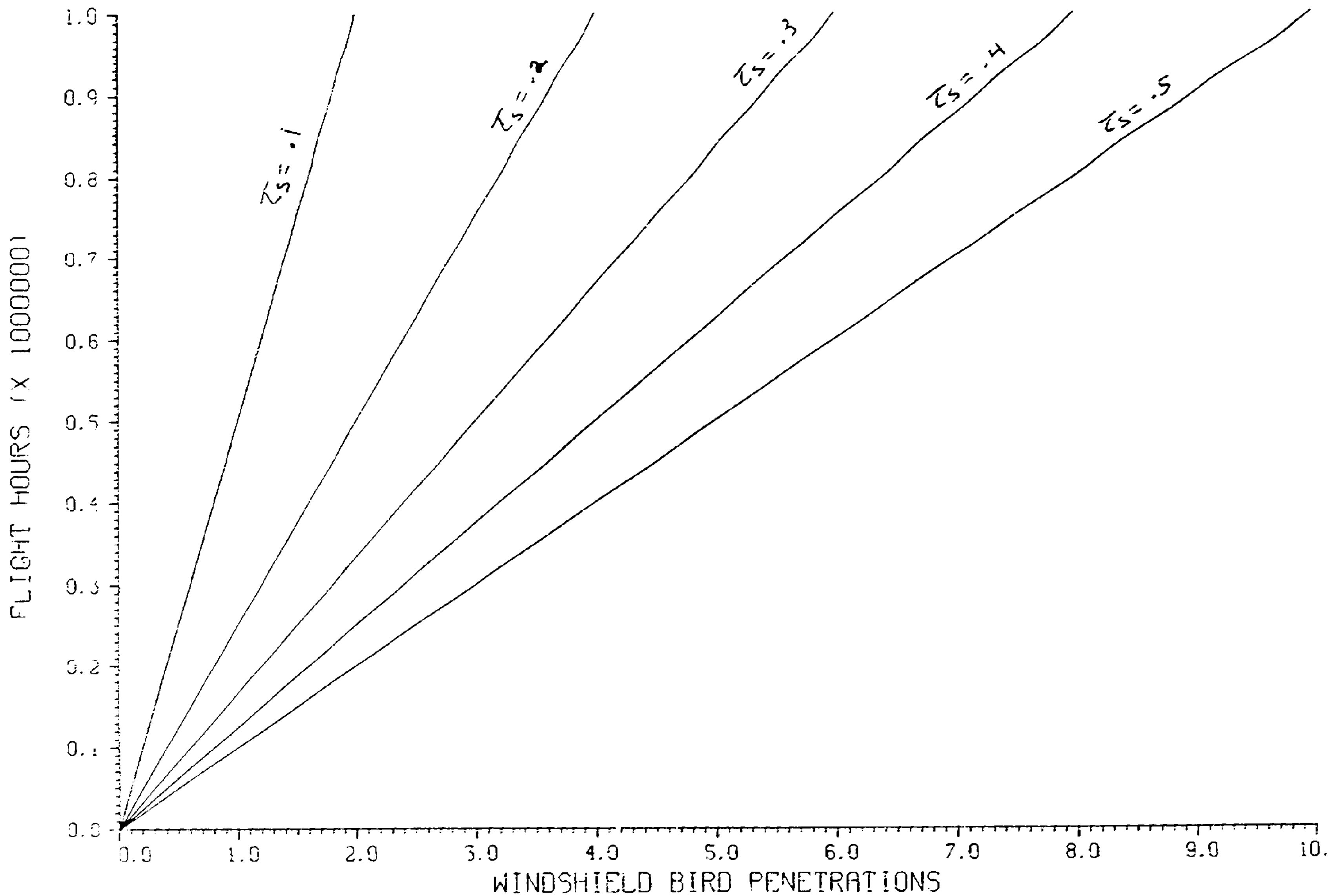


FIG. 19 F-15 PRESENT FLEET, PRESENT WINDSHIELD CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

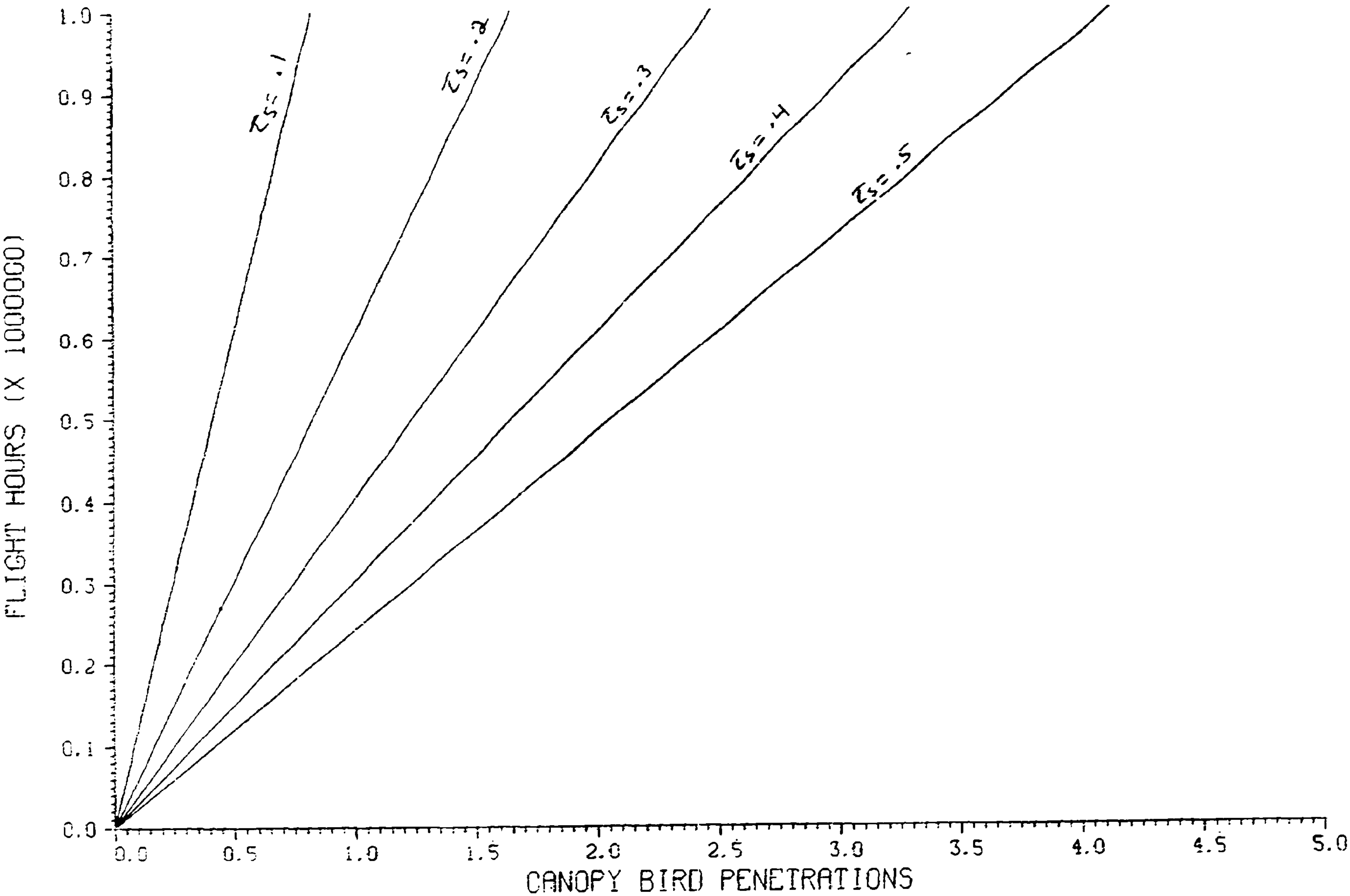


FIG. 20 F-15 PRESENT FLEET, PRESENT CANOPY CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

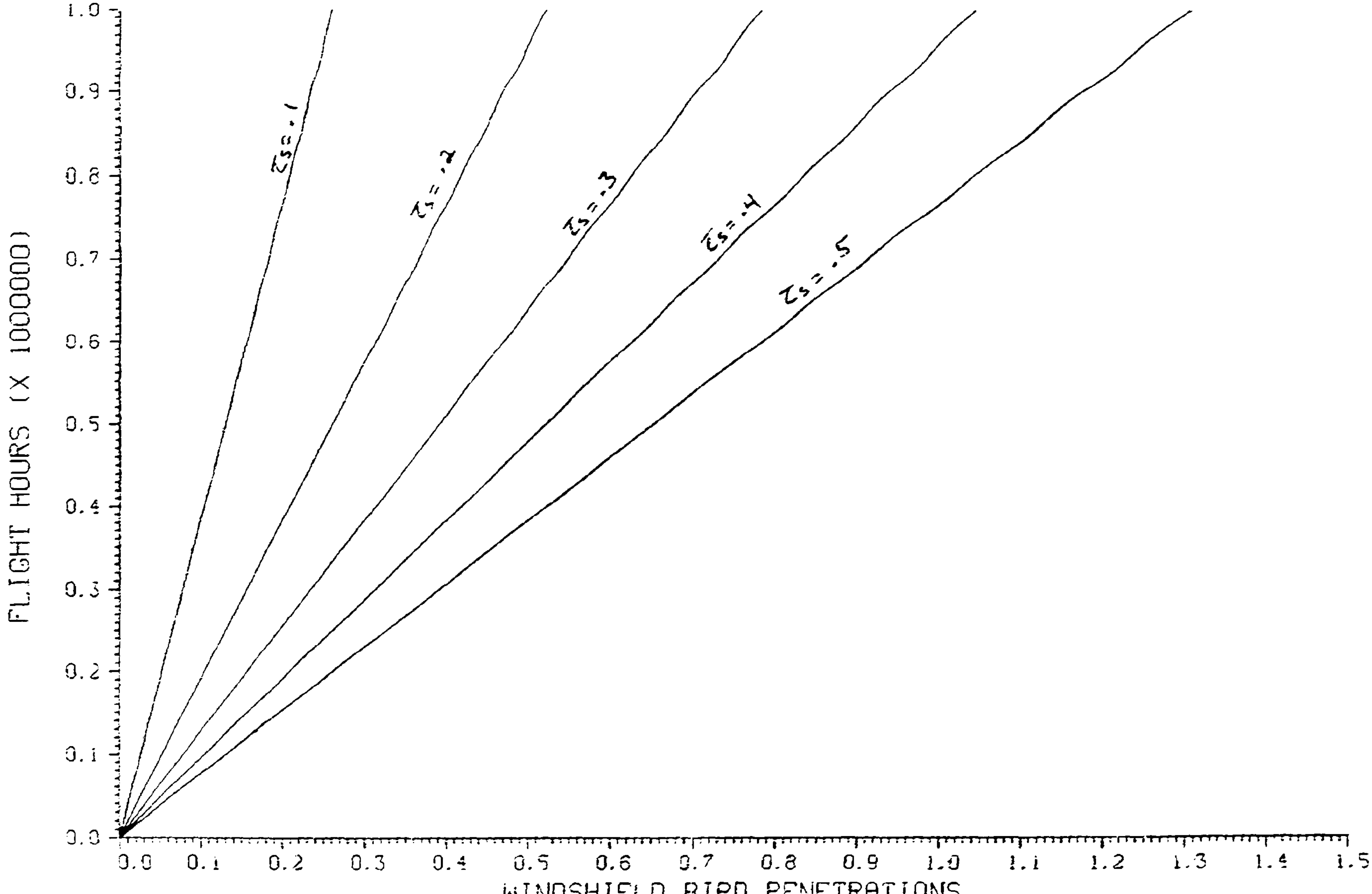


FIG. 21 F-15 PRESENT FLEET, PRESENT WINDSHIELD CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

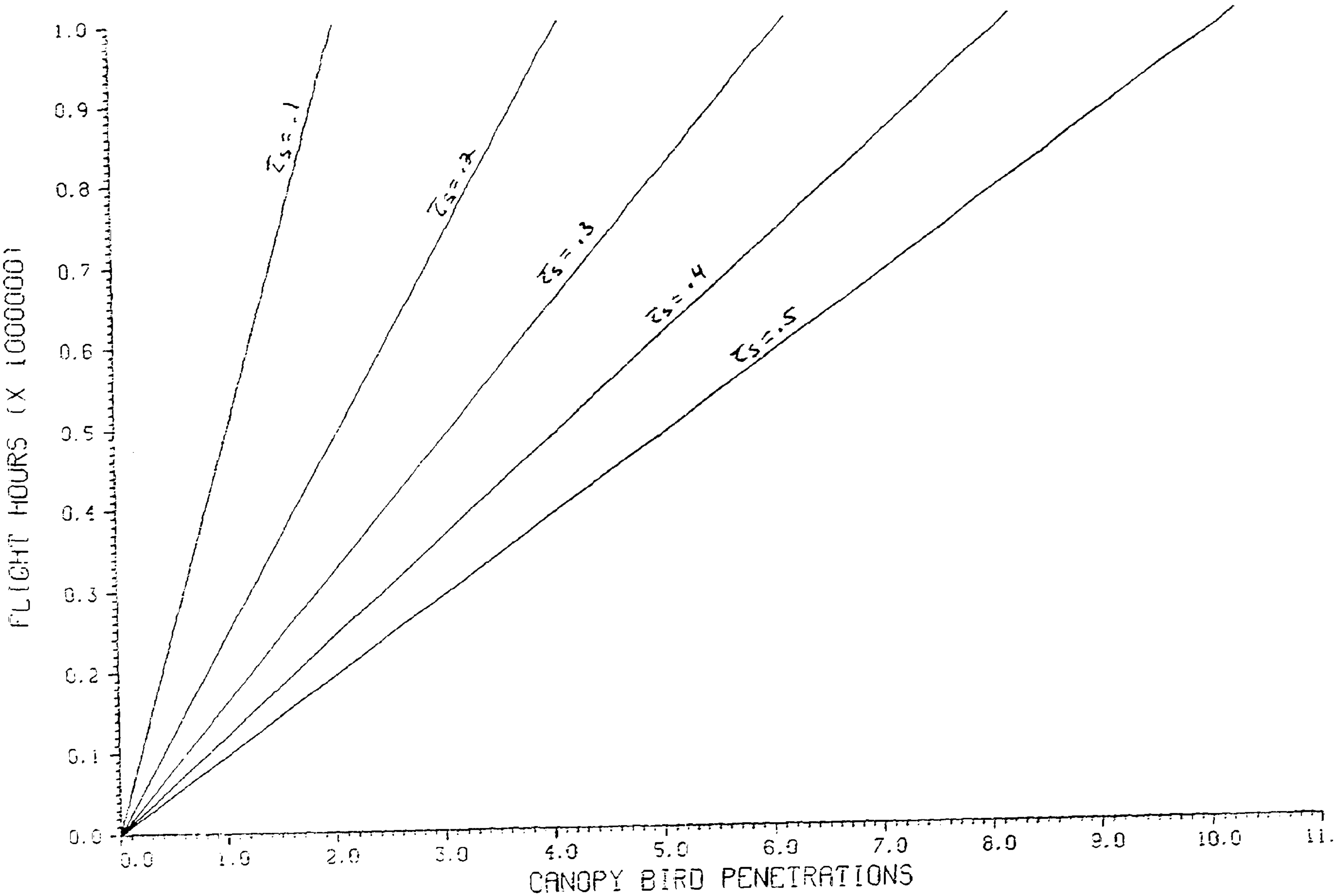


FIG. 22 F-15 PRESENT FLEET, PRESENT CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

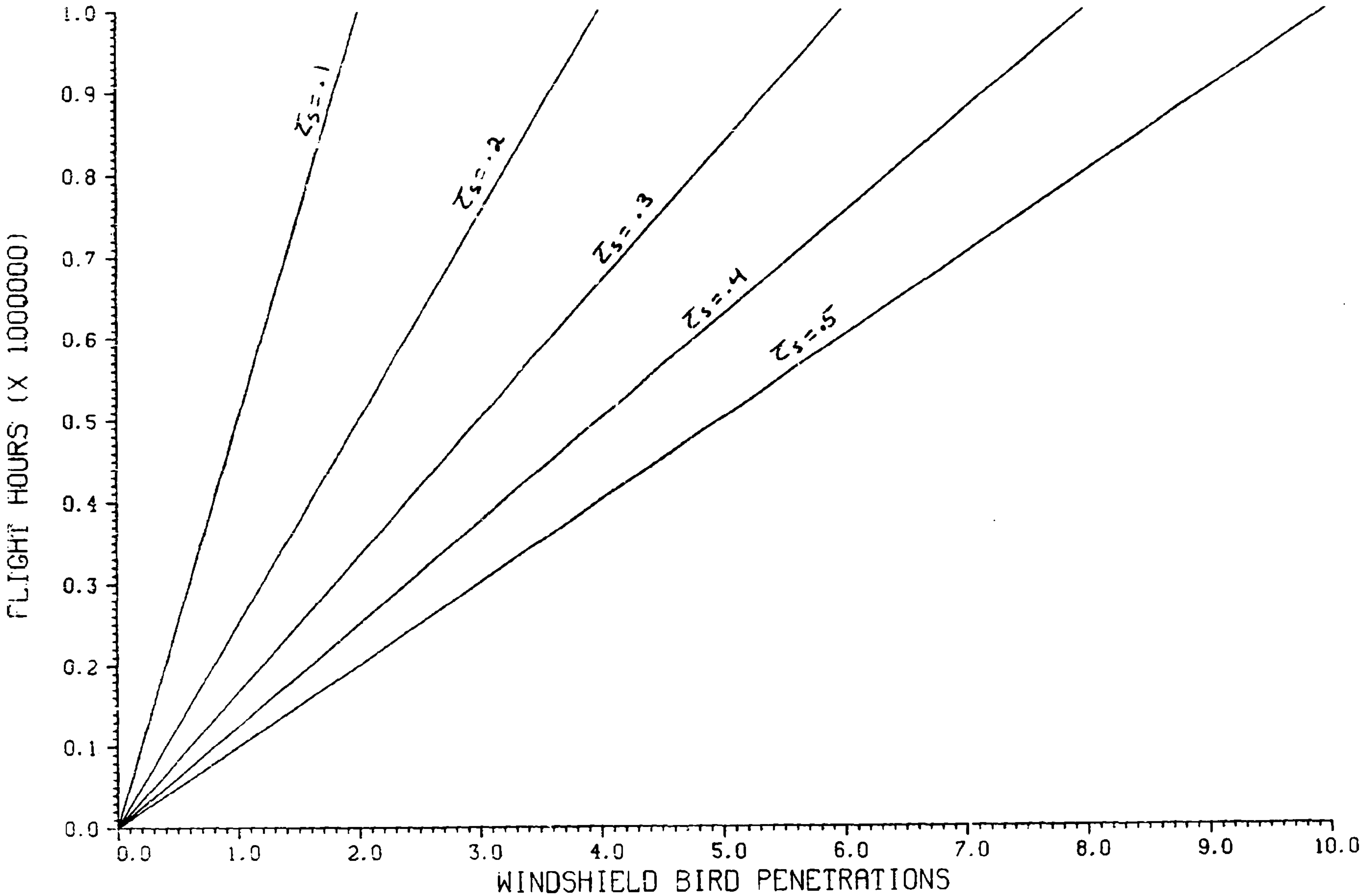


FIG. 23 F-15 RPD, PRESENT WINDSHIELD CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

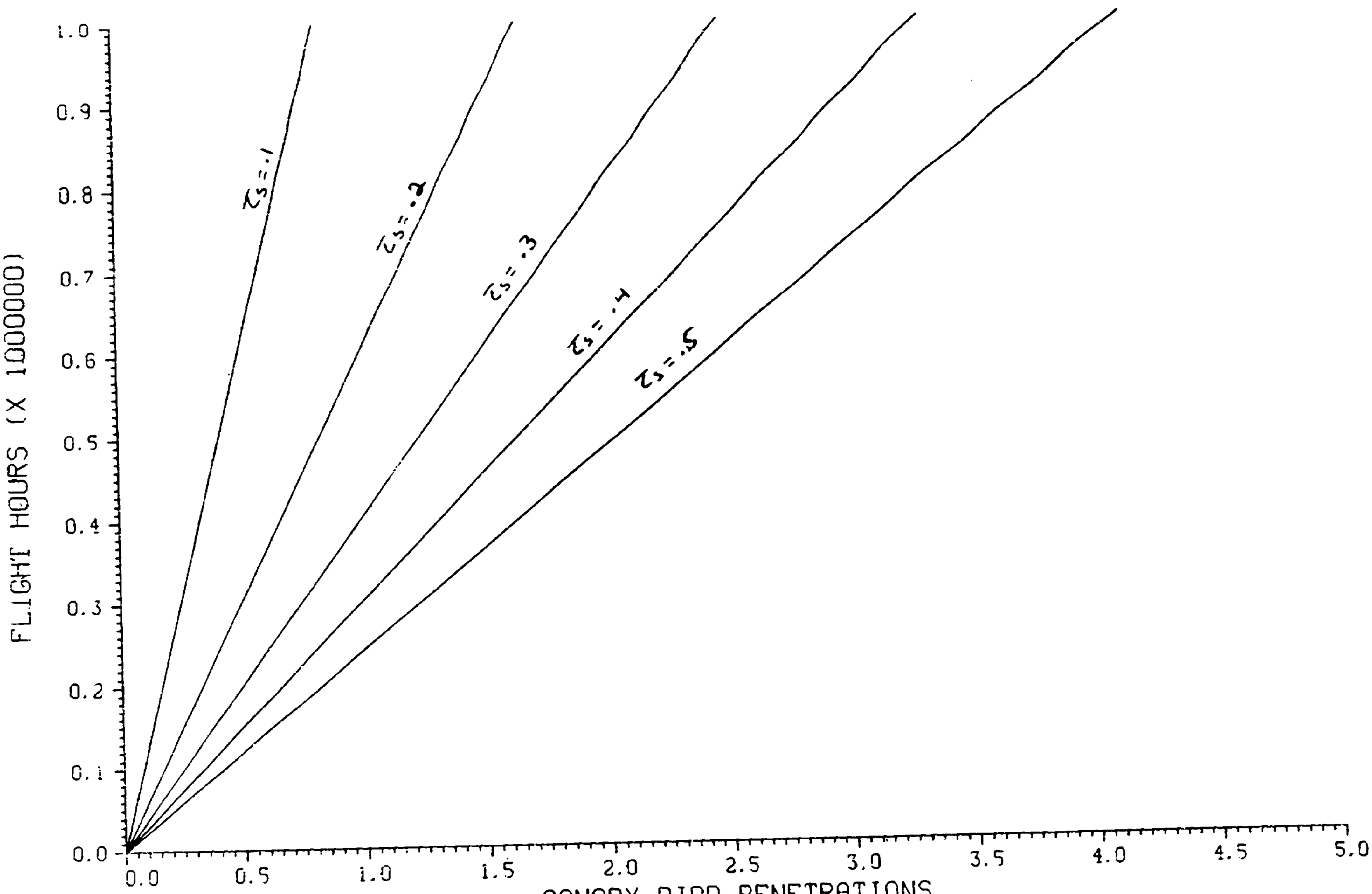


FIG. 24 F-15 RPD, PRESENT CANOPY CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

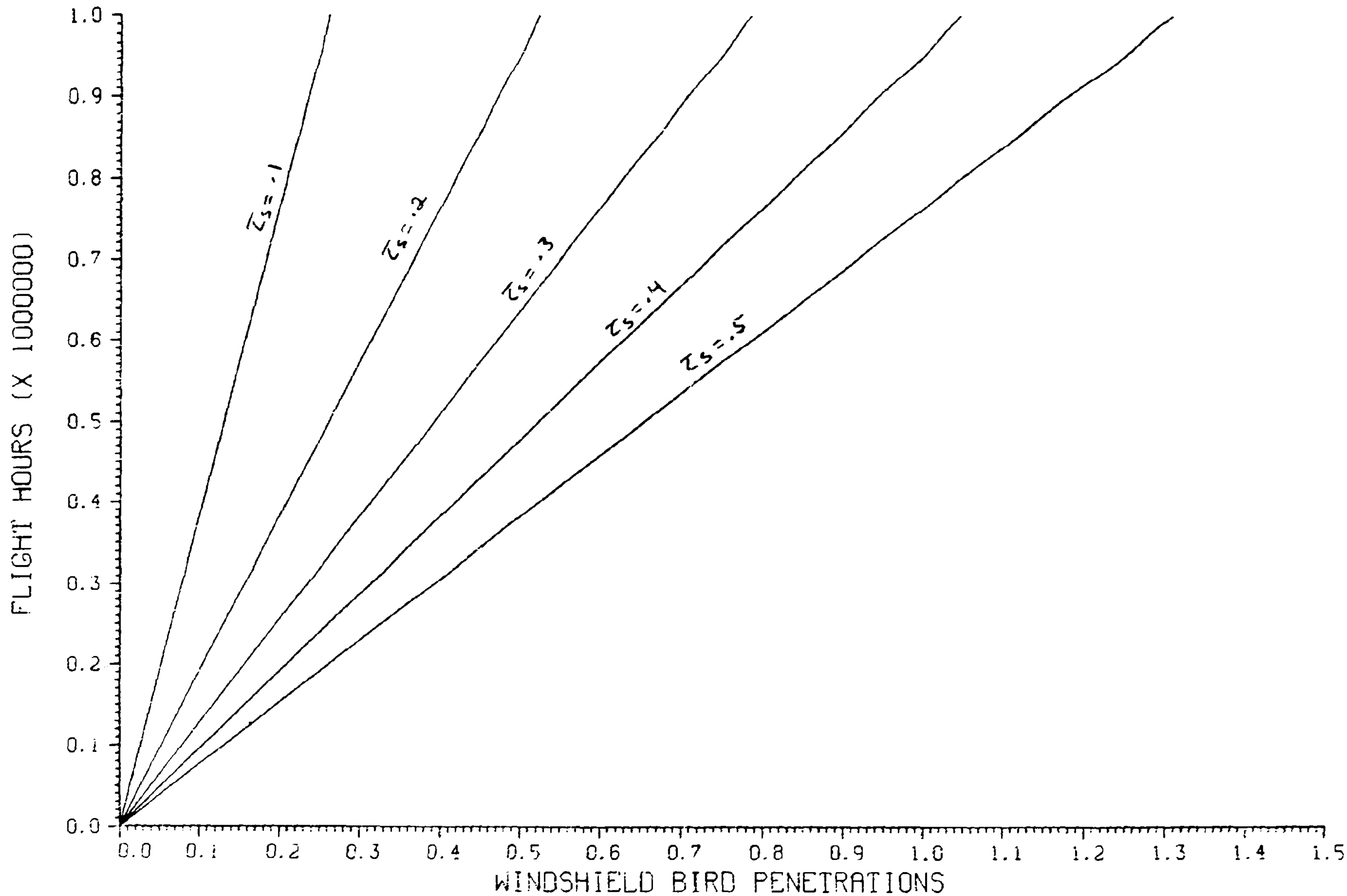


FIG. 25 F-15 RPD, PRESENT WINDSHIELD CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

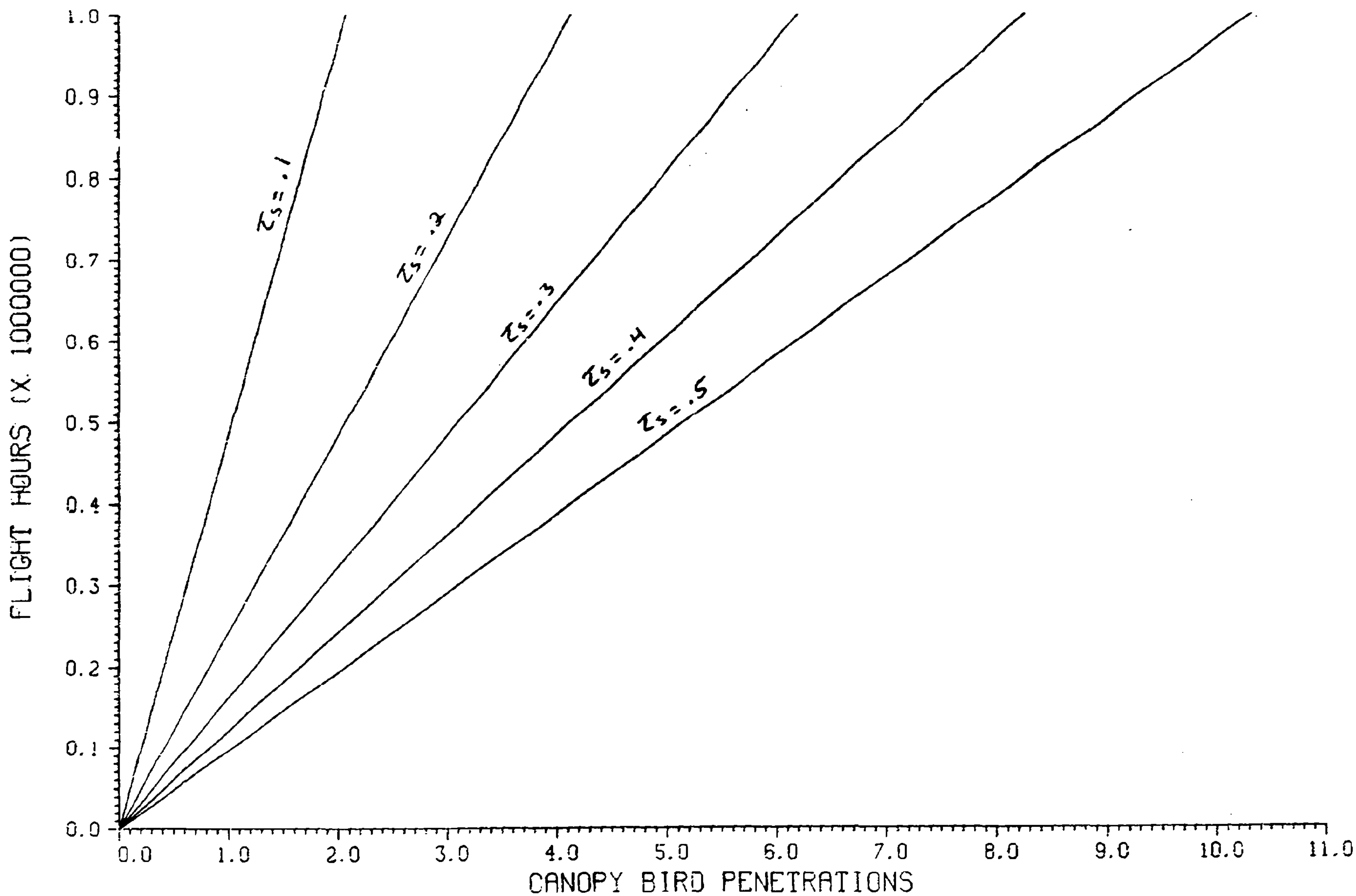


FIG. 26 F-15 RPD, PRESENT CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

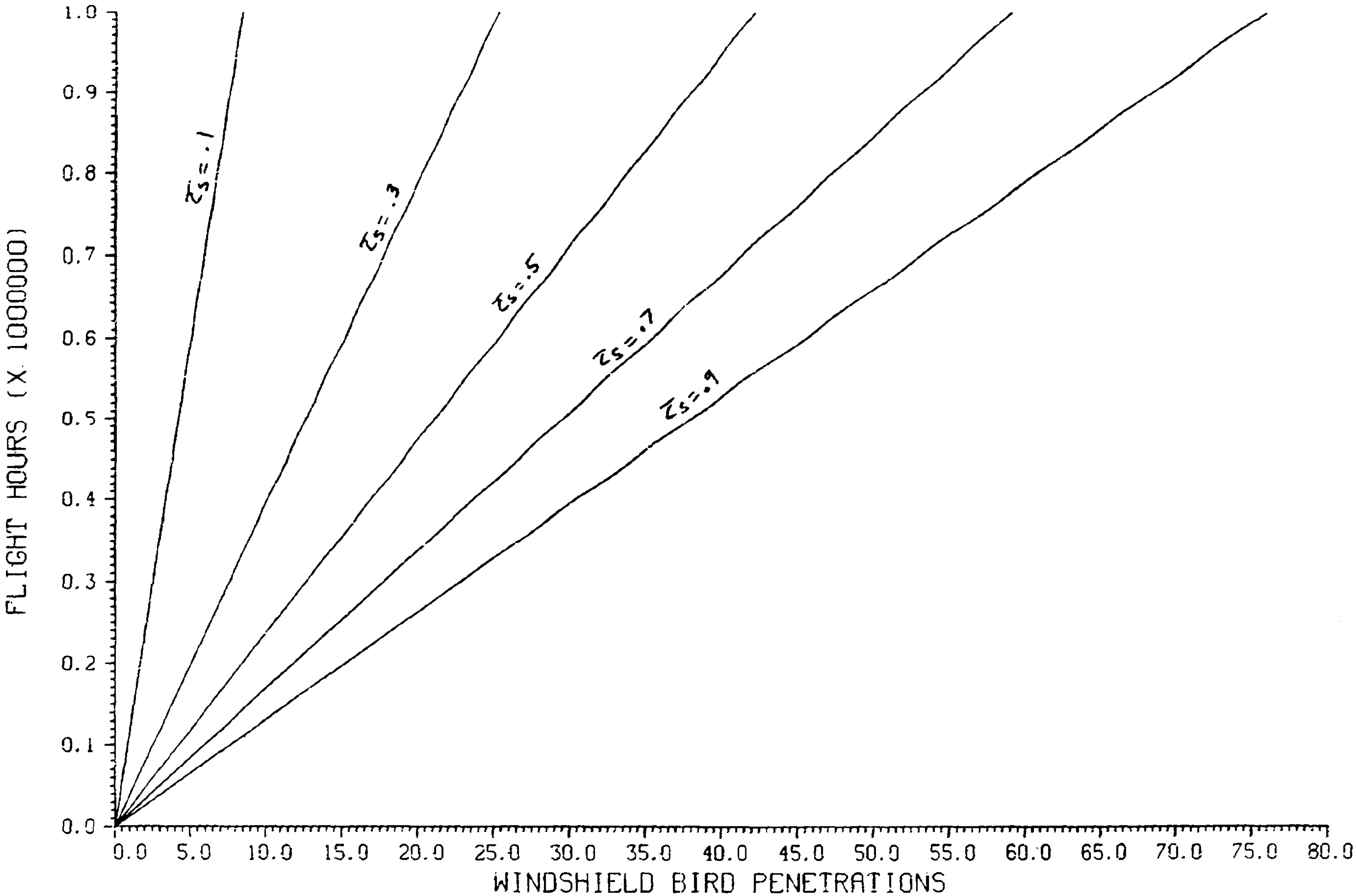


FIG. 27 F-15 RPD, PRESENT WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

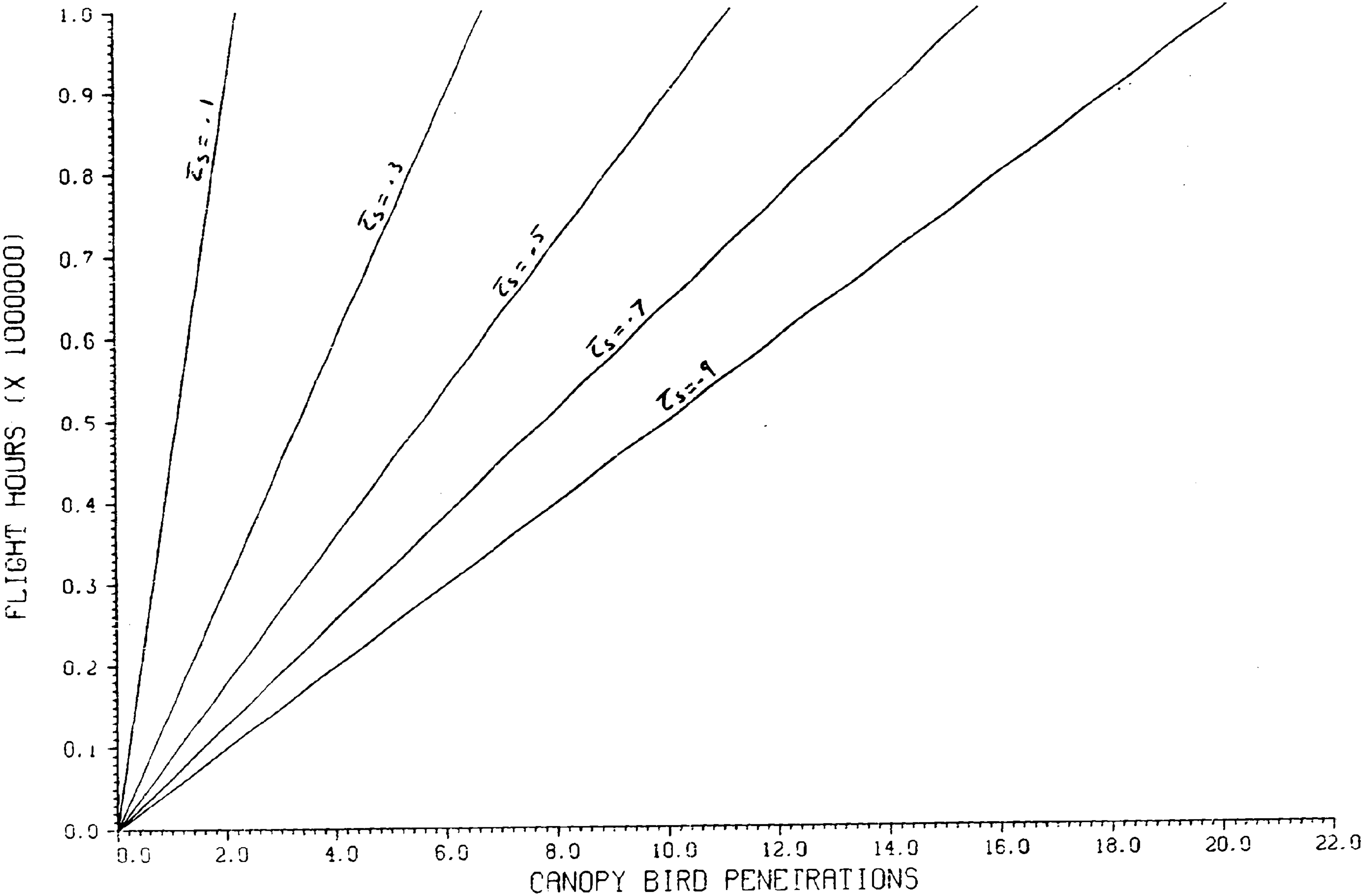


FIG. 28 F-15 RPD, PRESENT CANOPY CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

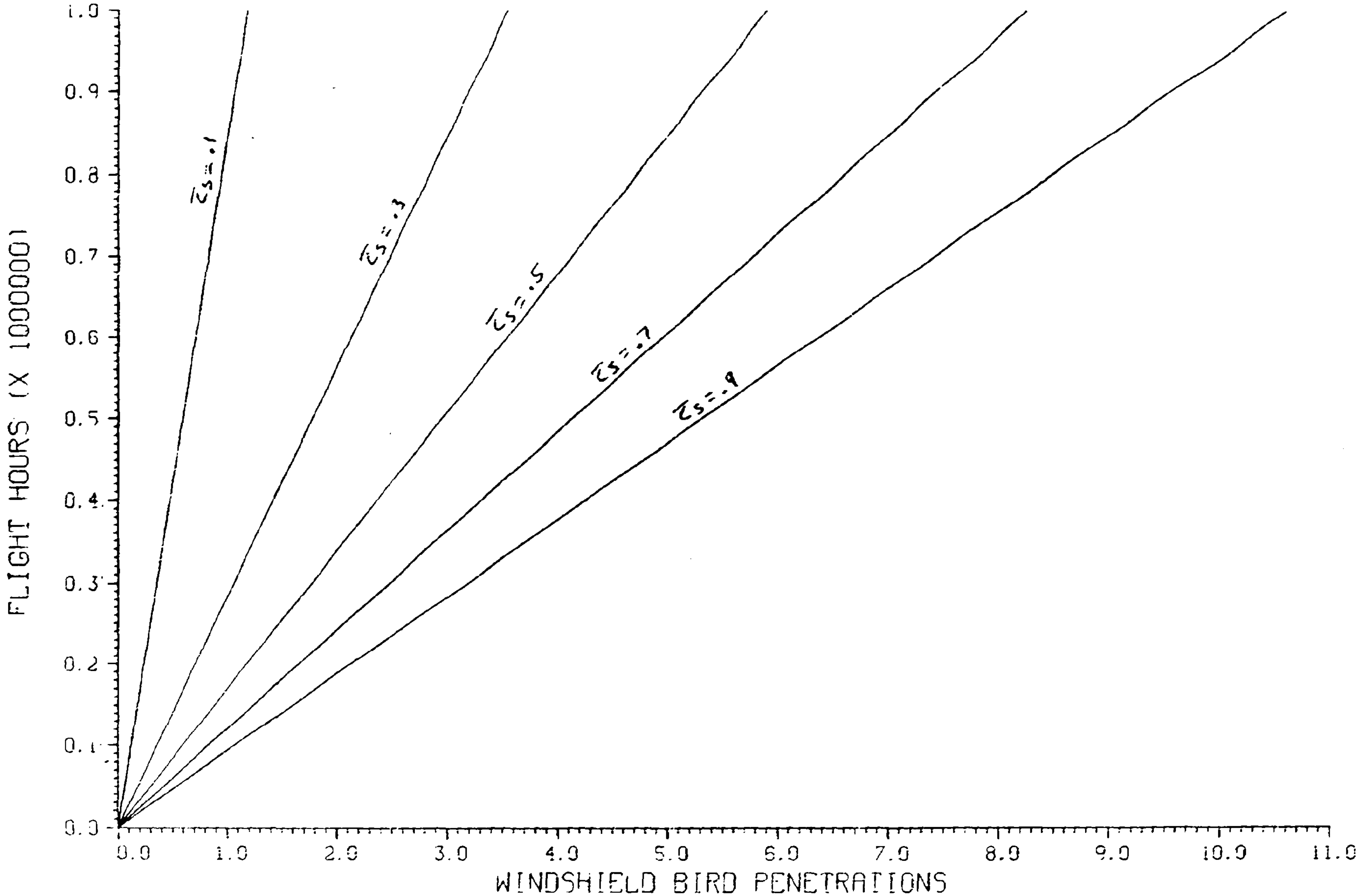


FIG. 29 F-15 RPD, PRESENT WINDSHIELD CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

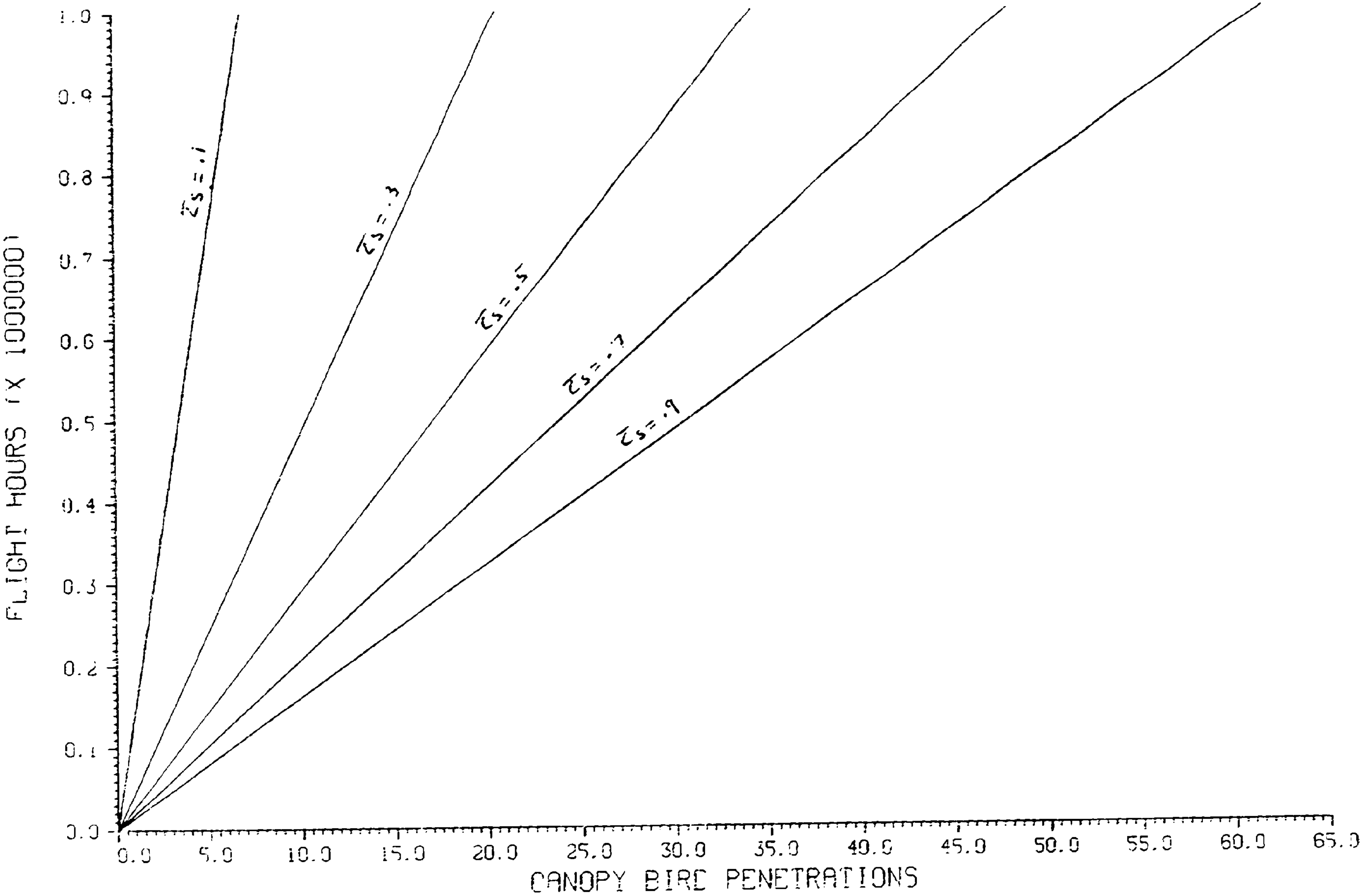


FIG. 30 F-15 RPD, PRESENT CANOPY CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

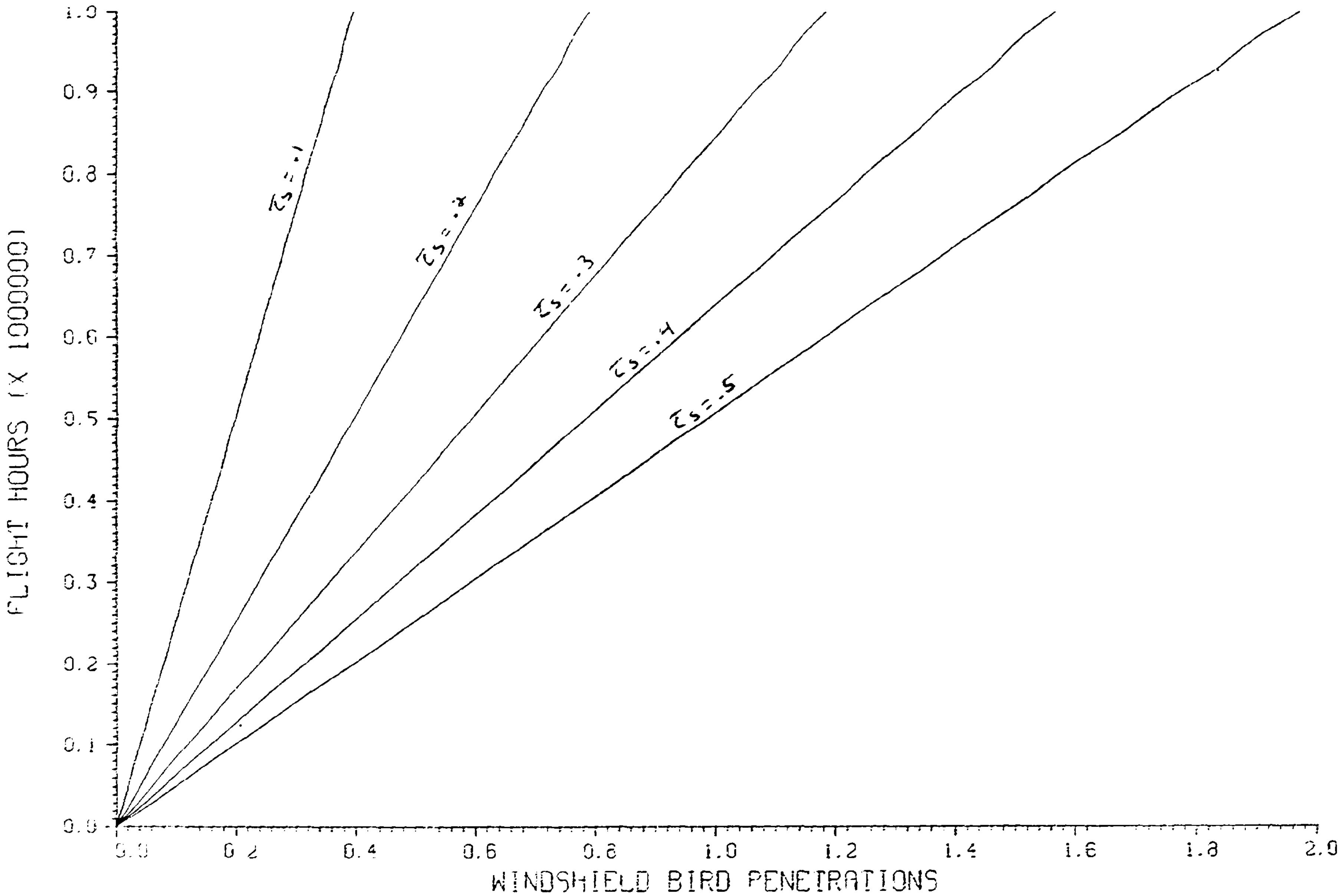


FIG 31 F-15 RPD, 450 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

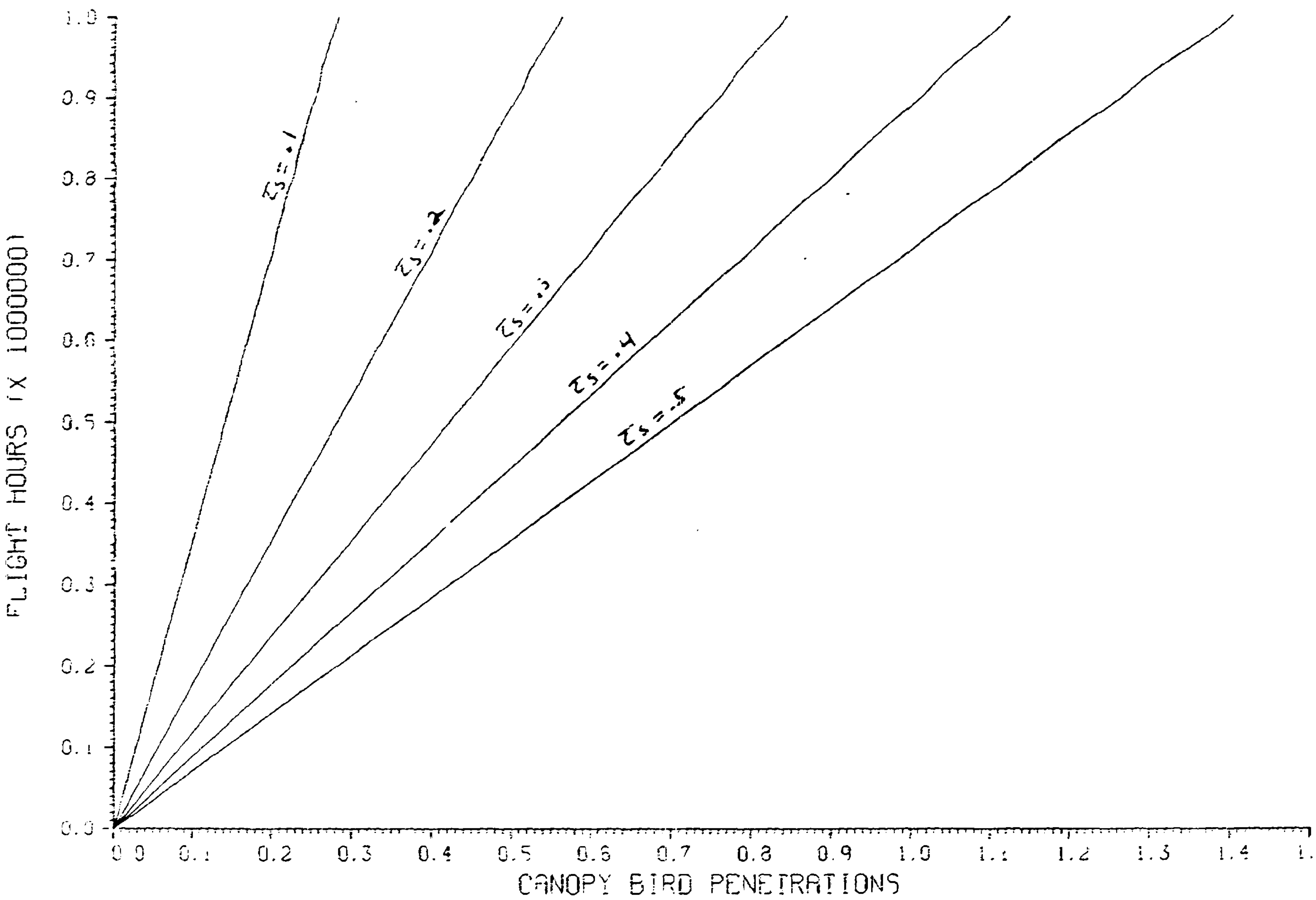


FIG. 32 F-15 RPD, 300 KT. CANOPY CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

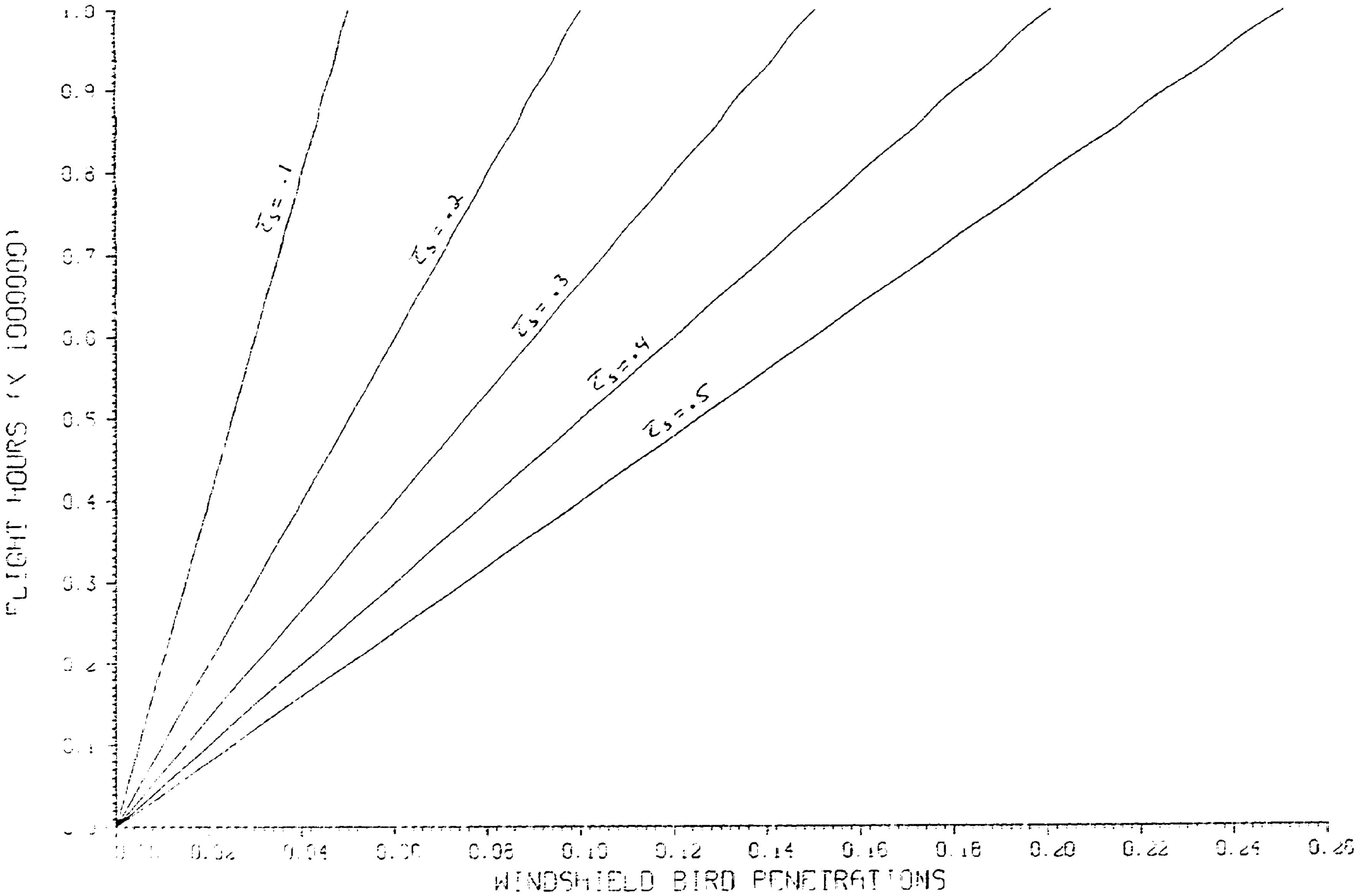


FIG 33 F 15 RPD, 450 KT. WINDSHIELD CAPABILITY
EUROPE, AIR TO AIR (0 5000 FT. AGL)

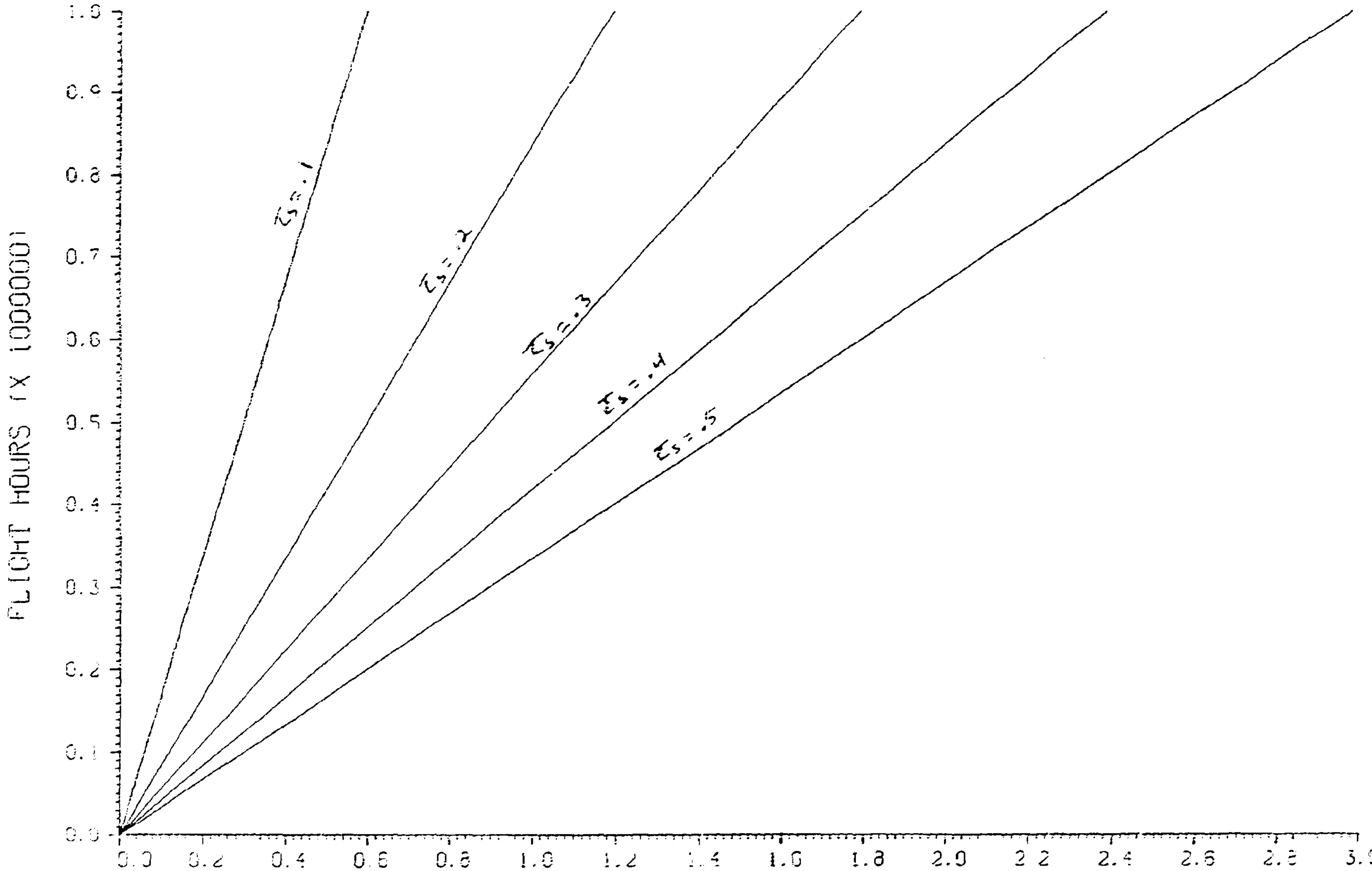


FIG. 34 F-15 RPD, 300 KT. CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

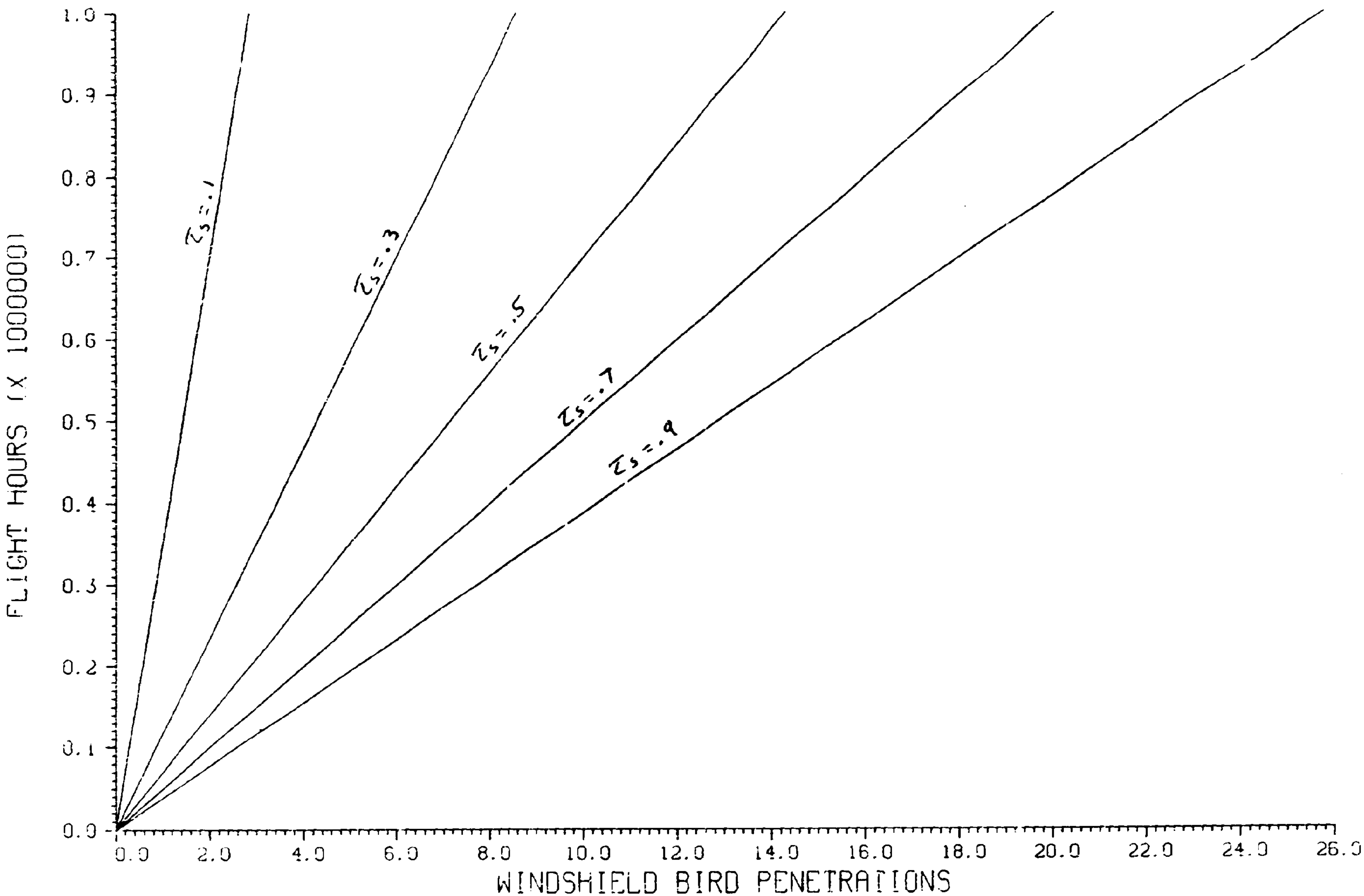


FIG. 35 F-15 RPD, 450 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

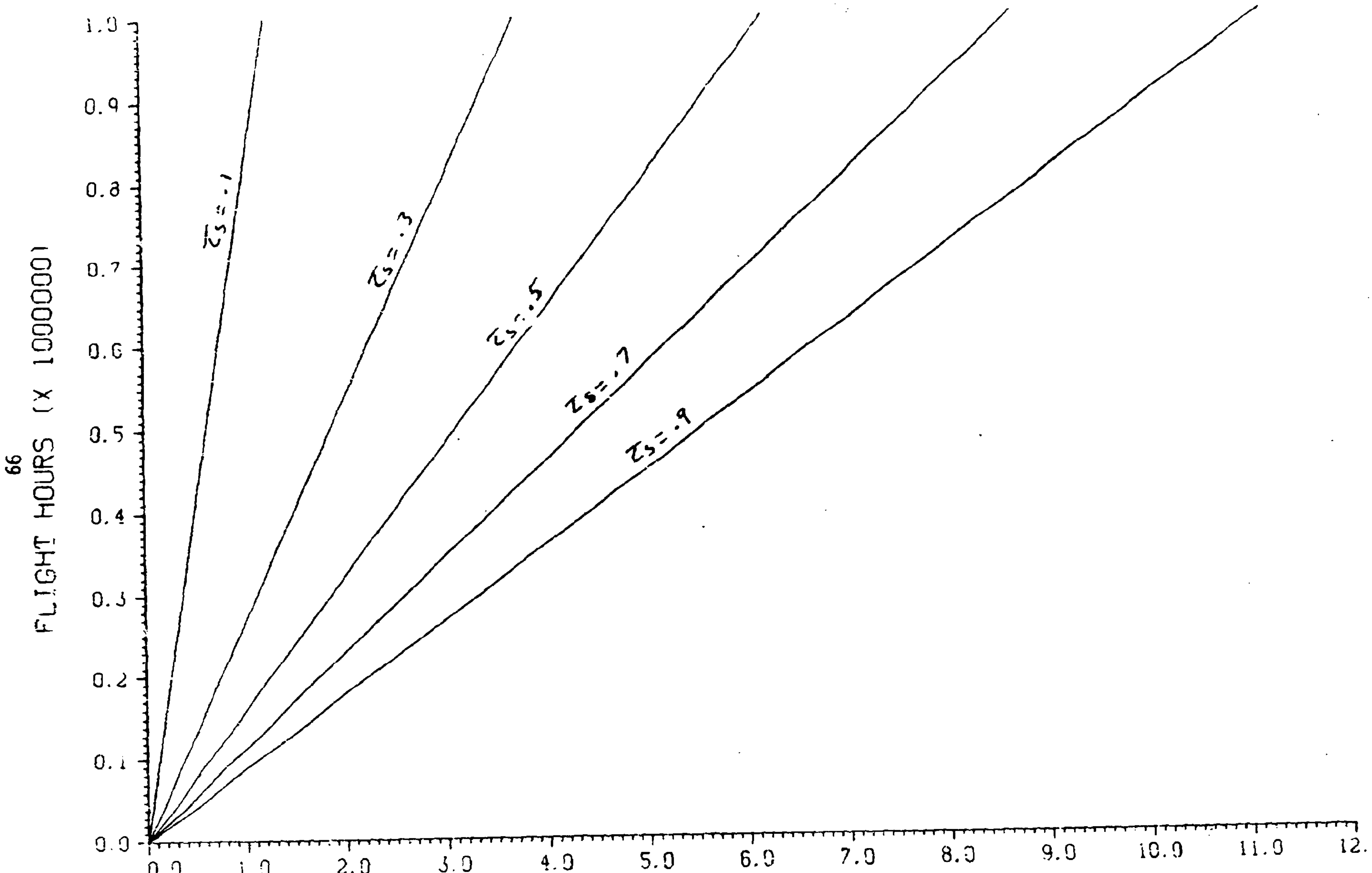


FIG. 36 F-15 RPD, 300 KT. CANOPY CAPABILTIY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

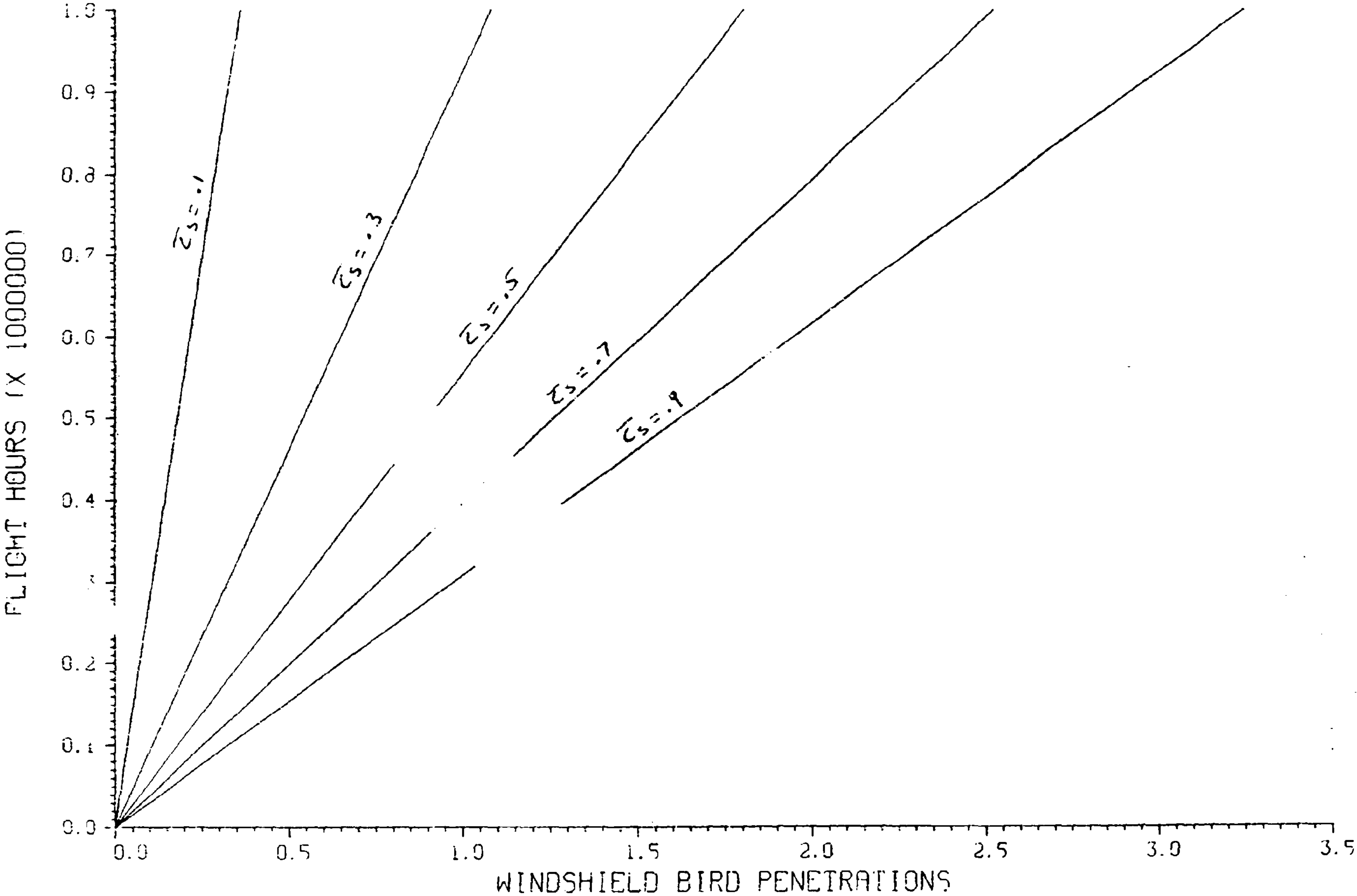


FIG. 37 F-15 RPD, 450 KT. WINDSHIELD CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

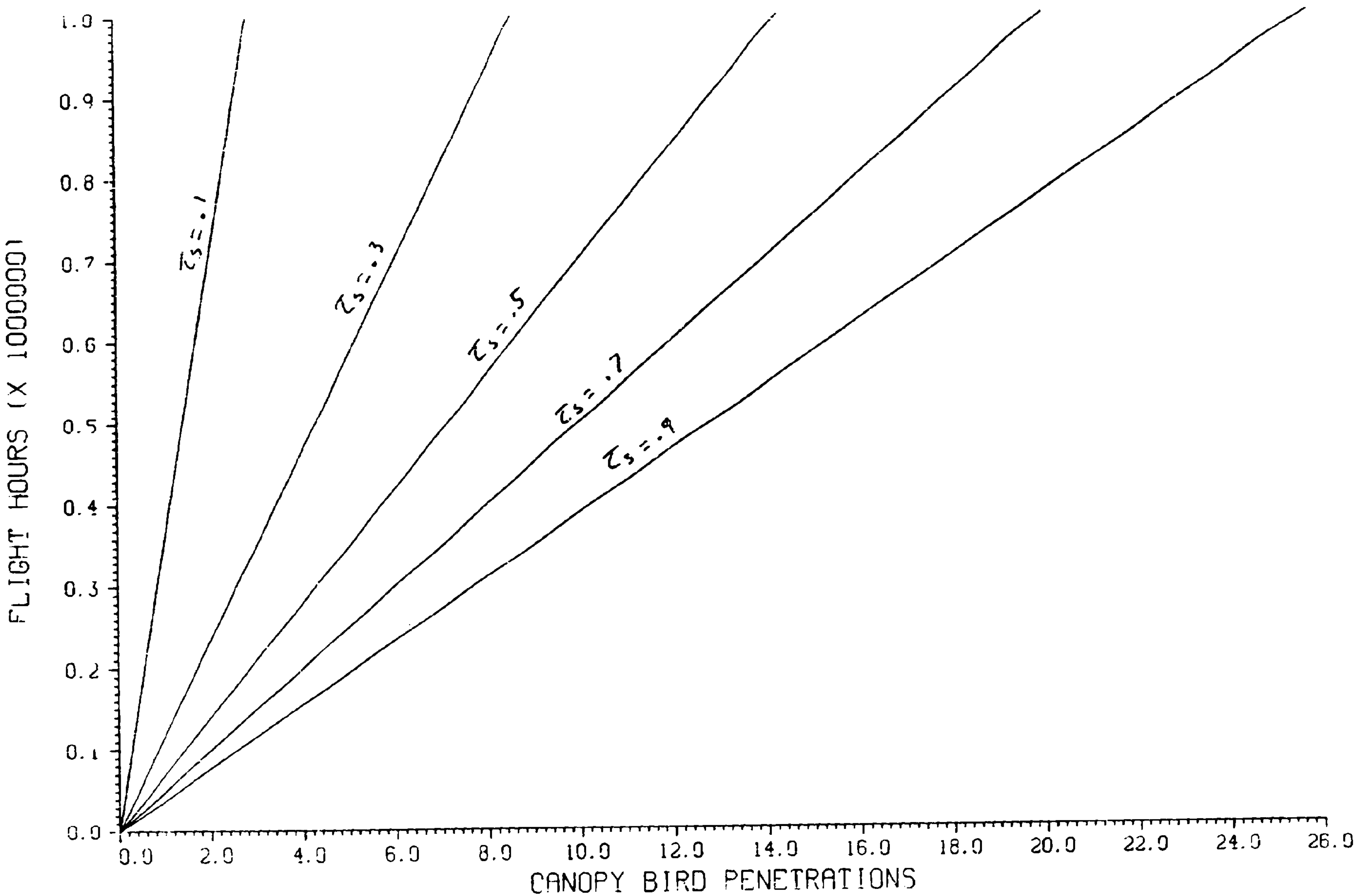


FIG. 38 F-15 RPD, 300 KT. CANOPY CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

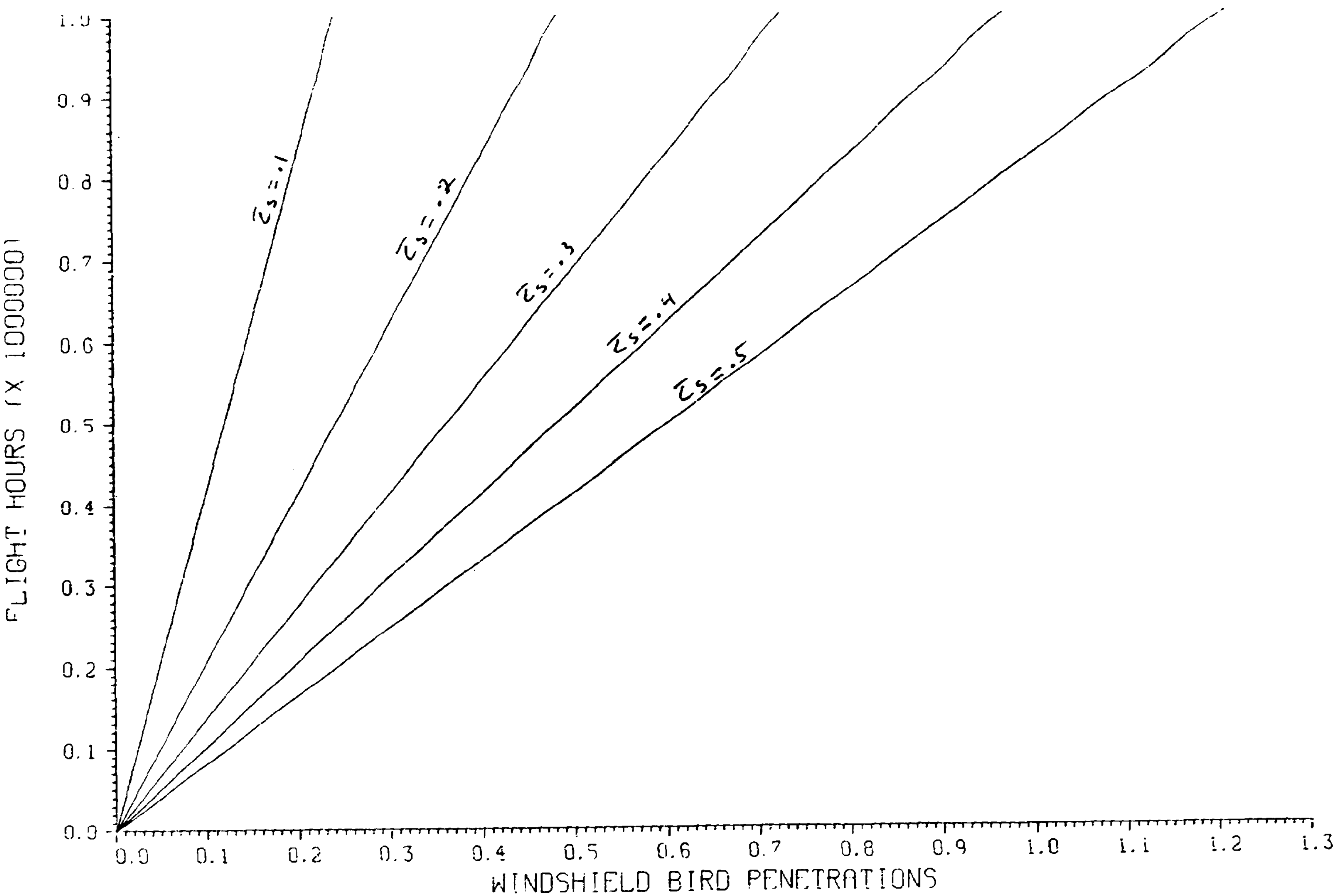


FIG. 39 F-15 RPD, 500 KT. WINDSHIELD CAPABILITY
CONUS AIR TO AIR (0-5000 FT. AGL)

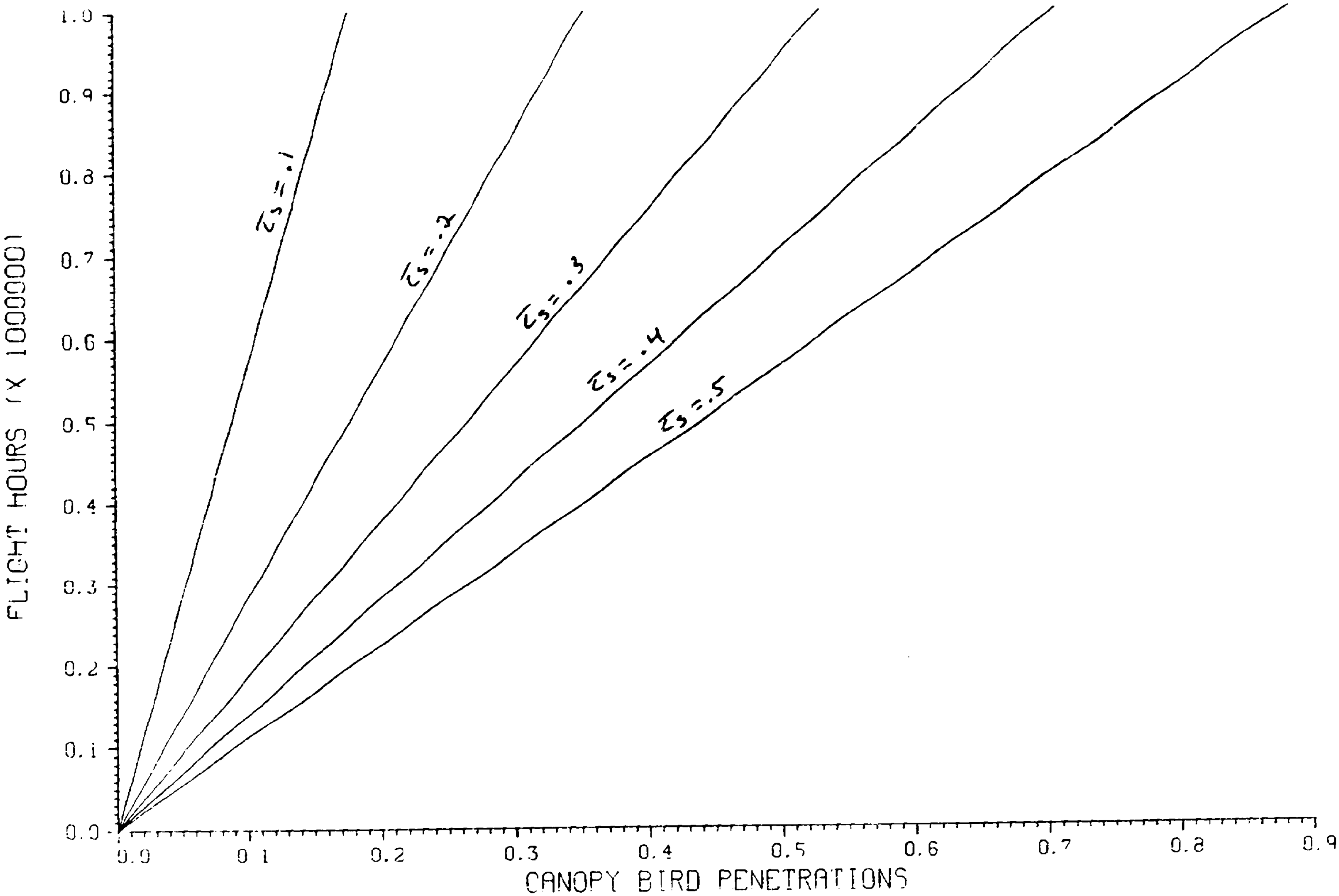


FIG. 40 F-15 RPD, 350 KT. CANOPY CAPABILITY
CONUS AIR TO AIR (0-5000 FT. AGL)

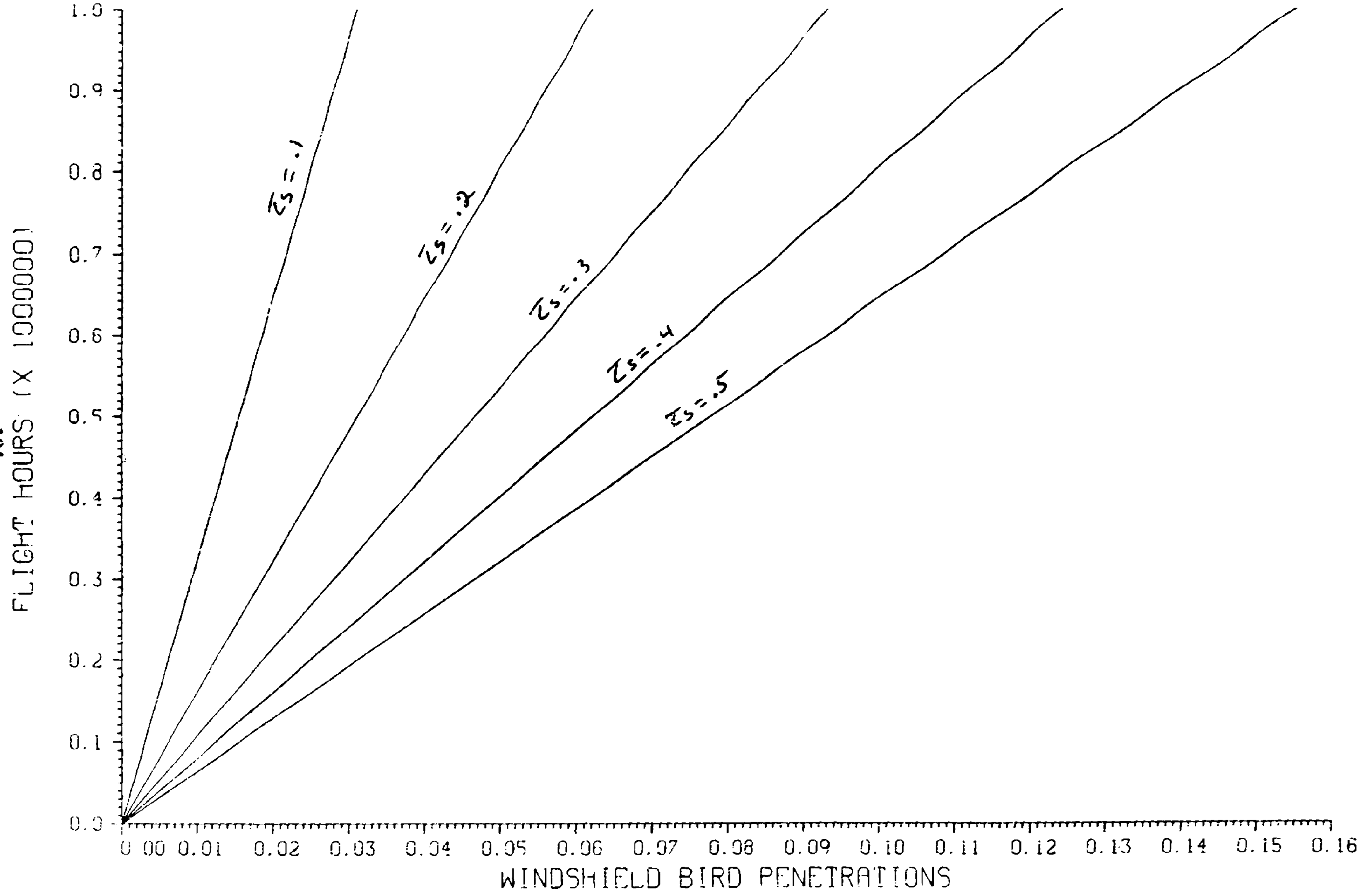


FIG 41 F-15 RPD, 500 KT. WINDSHIELD CAPABILITY
EUROPE AIR TO AIR (0-5000 FT. AGL)

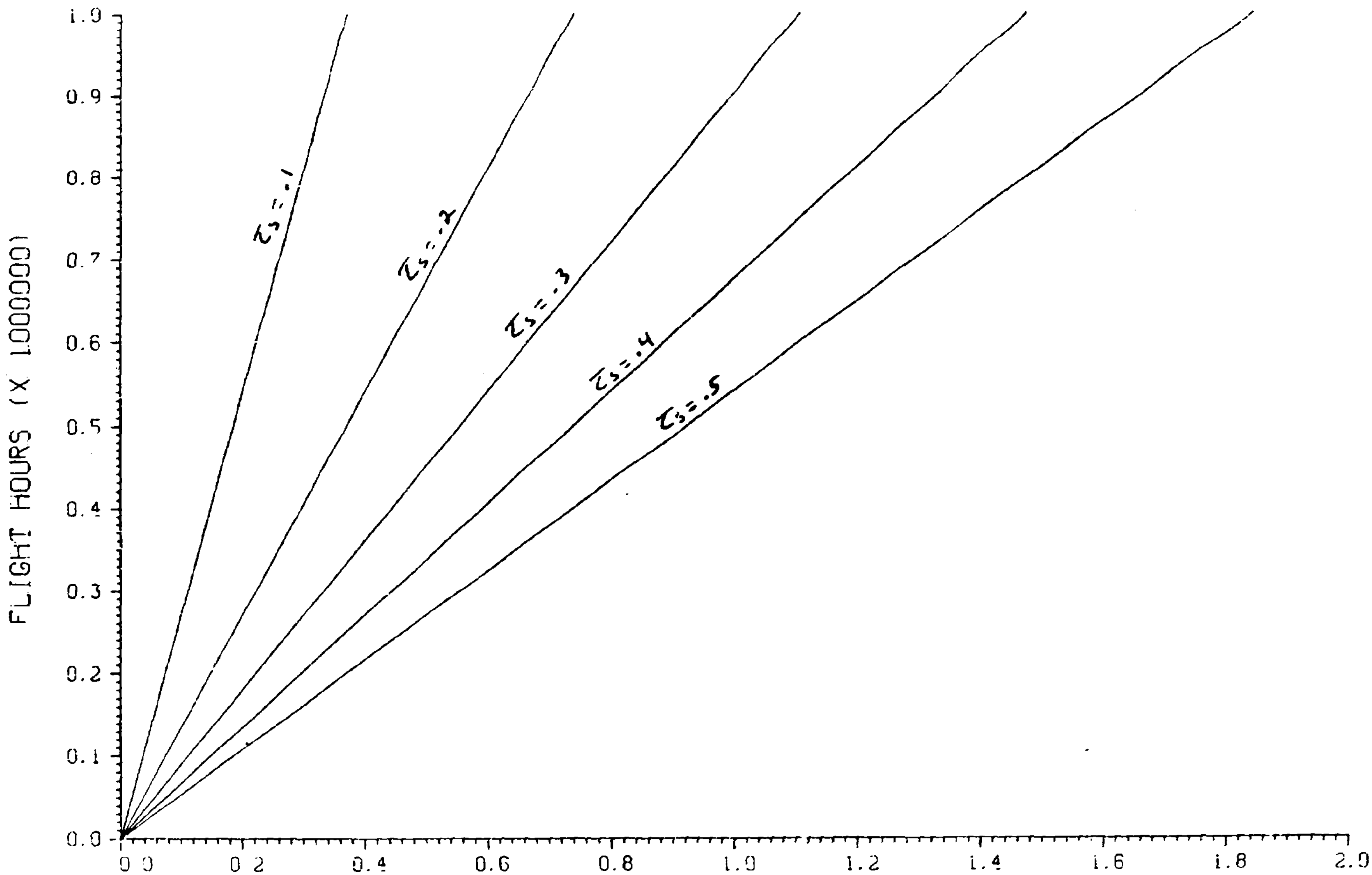


FIG. 42 F-15 RPD, 350 KT. CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

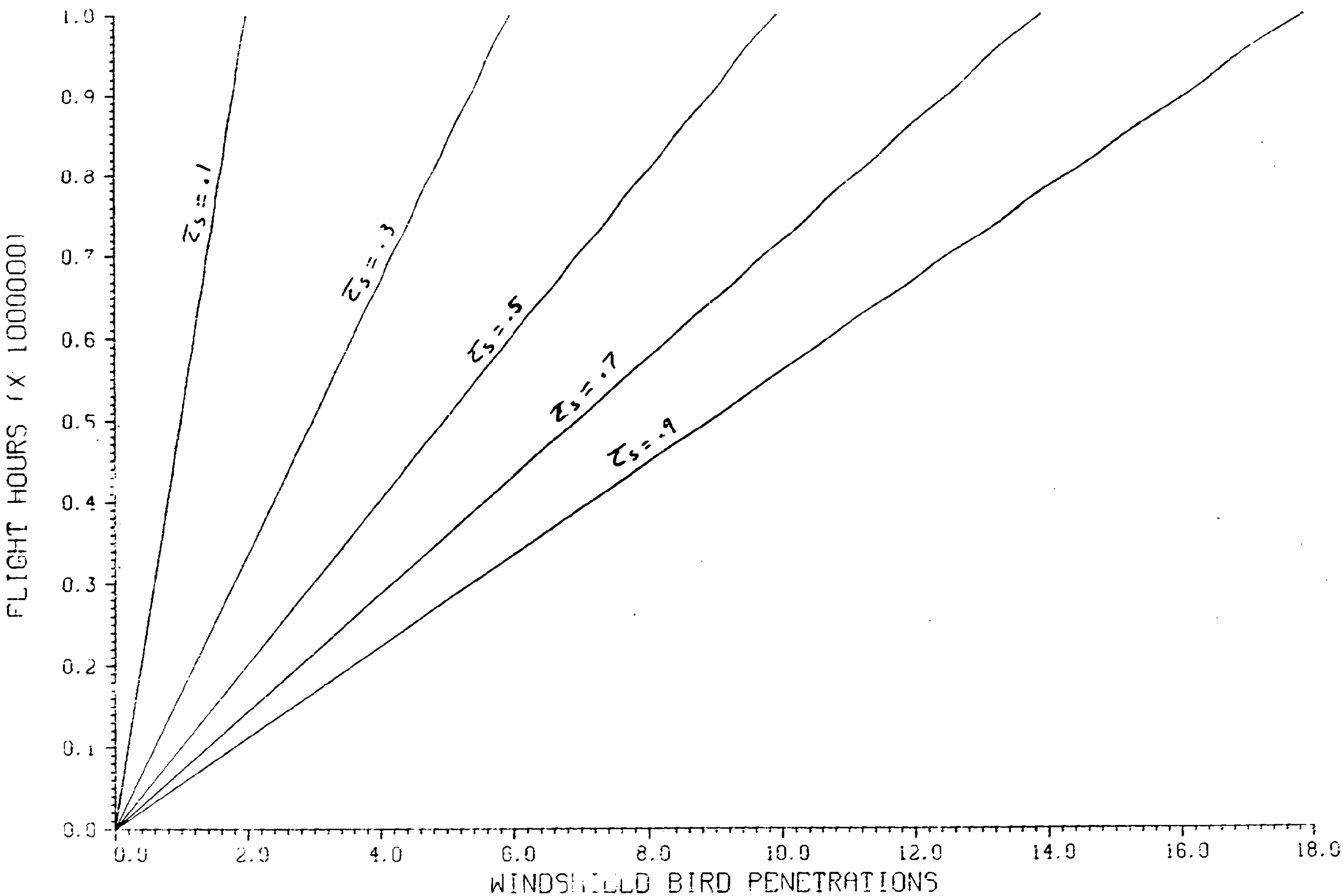


FIG. 43 F-15 RPD, 500 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

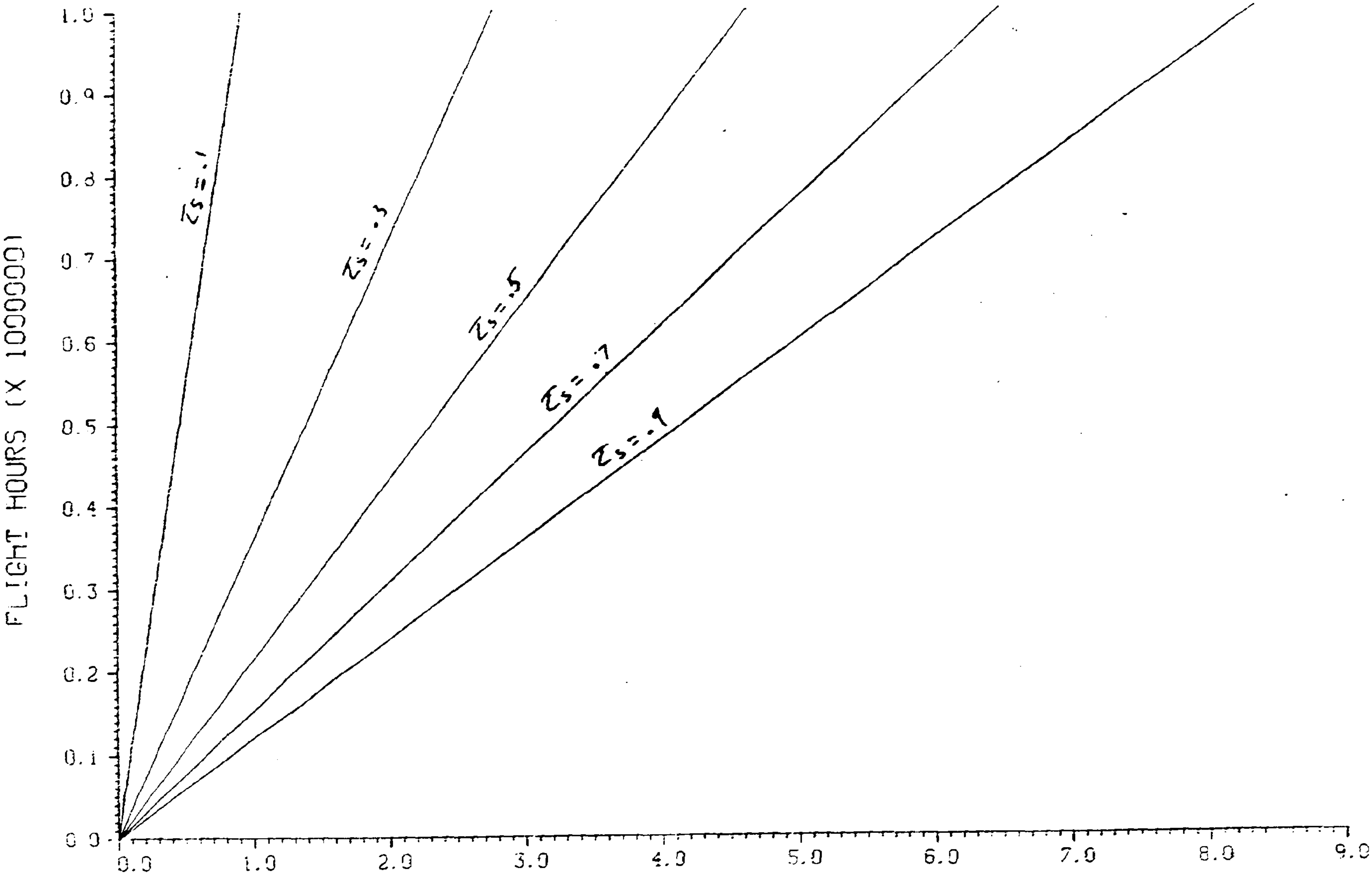


FIG 44 F-15 RPD, 350 KT. CANOPY CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

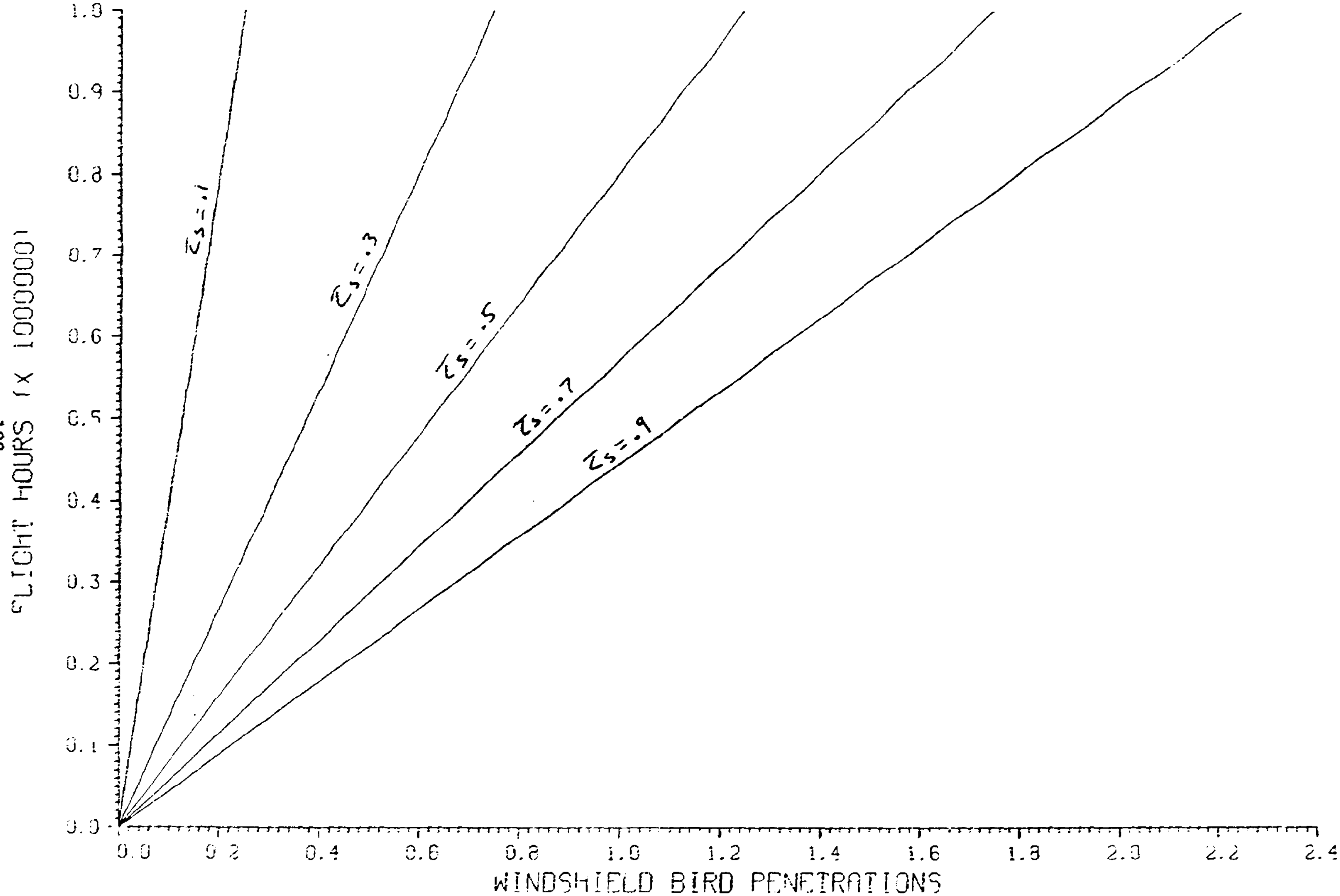


FIG. 45 F-15 RPD, 500 KT. WINDSHIELD CAPABILITY
EUROPE AIR TO GROUND (0-5000 FT. AGL)

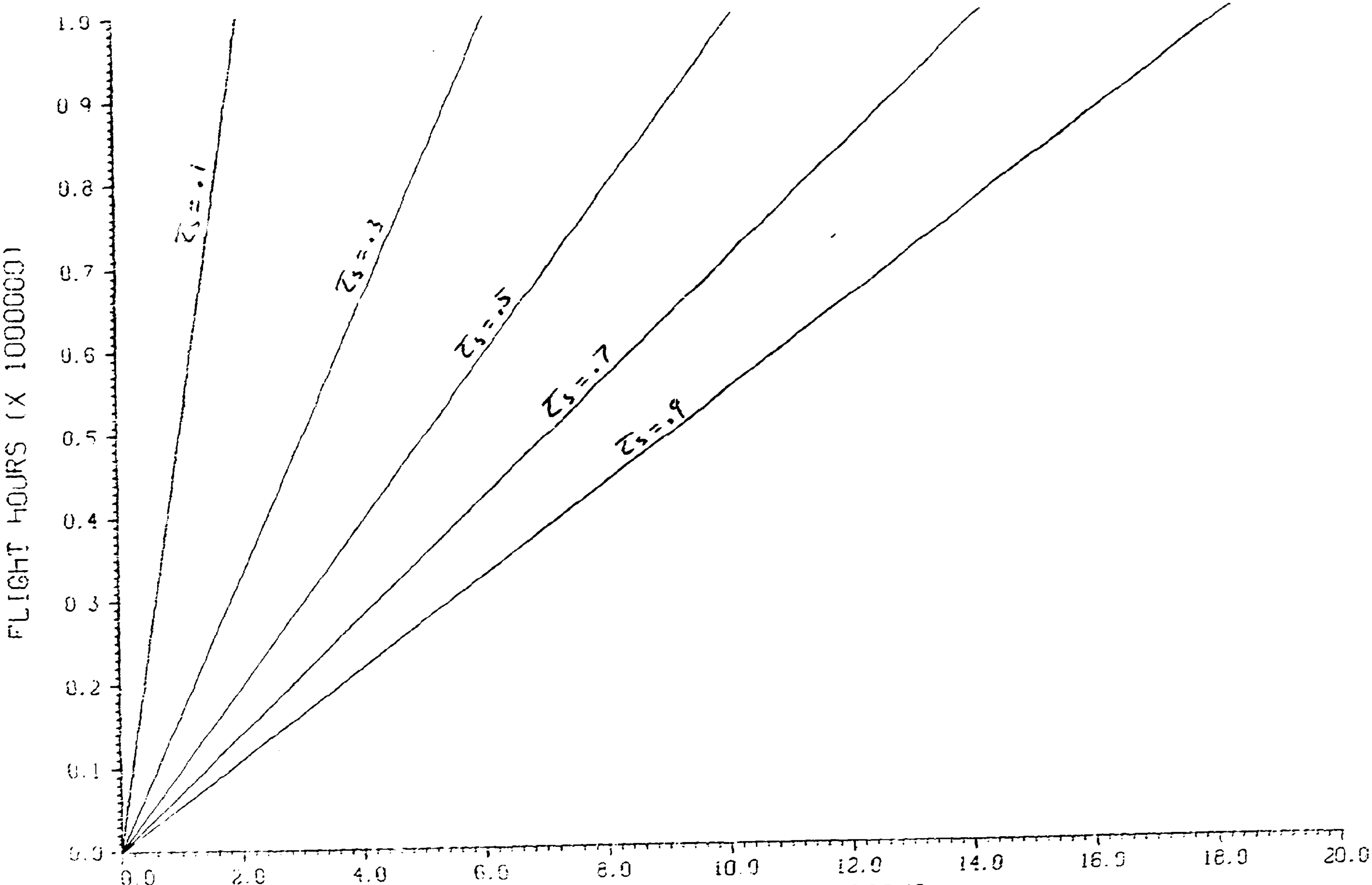


FIG. 46 F-15 RPD, 350 KT. CANOPY CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT AGL)

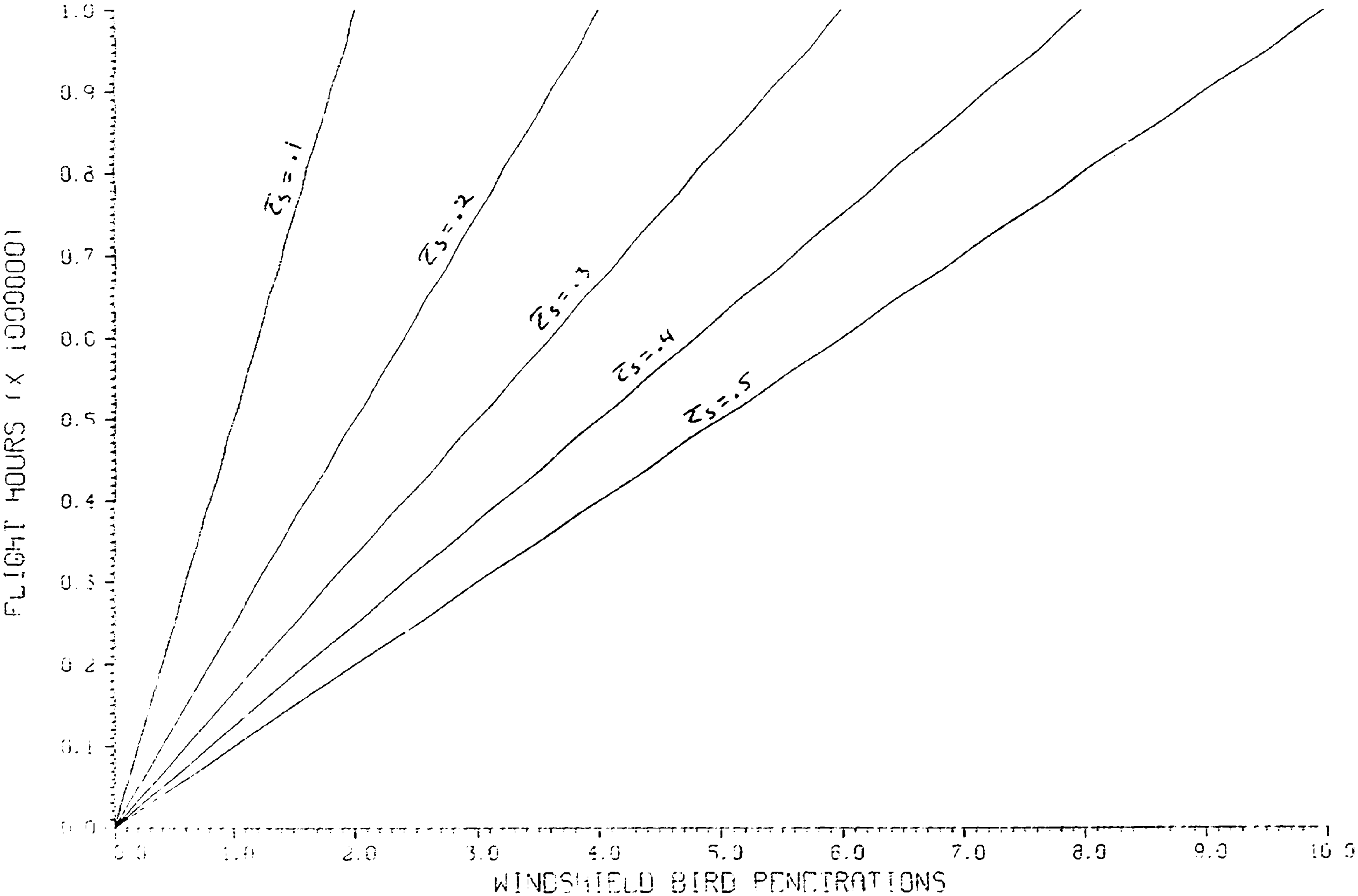


FIG 47 F-15 DRF PRESENT WINDSHIELD CAPABILITY
CONUS AIR TO AIR (0-5000 FT, AGL)

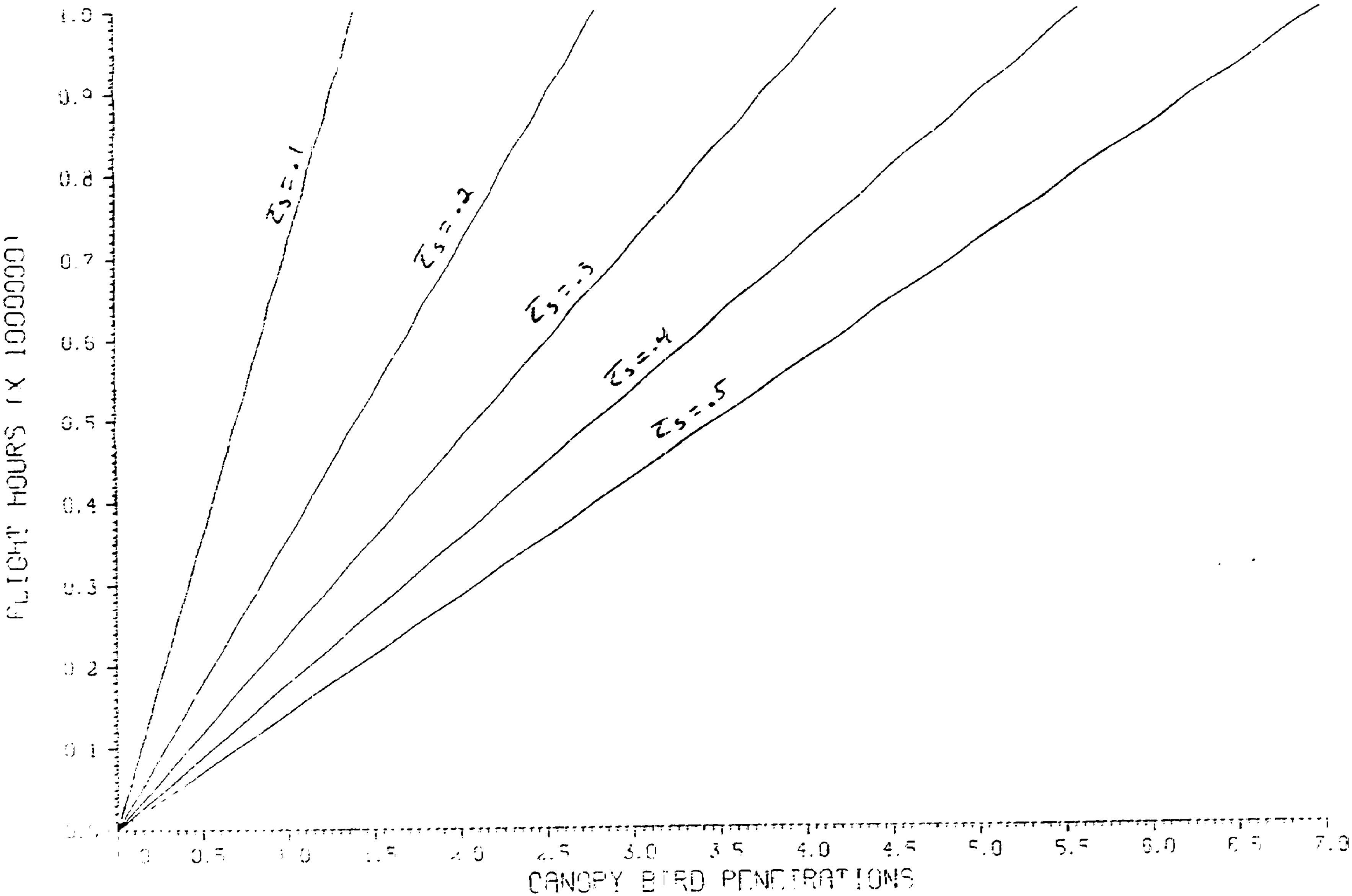


FIG. 48 F-15 ORF PRESENT CANOPY CAPABILITY
COMB AIR TO AIR ... ADL

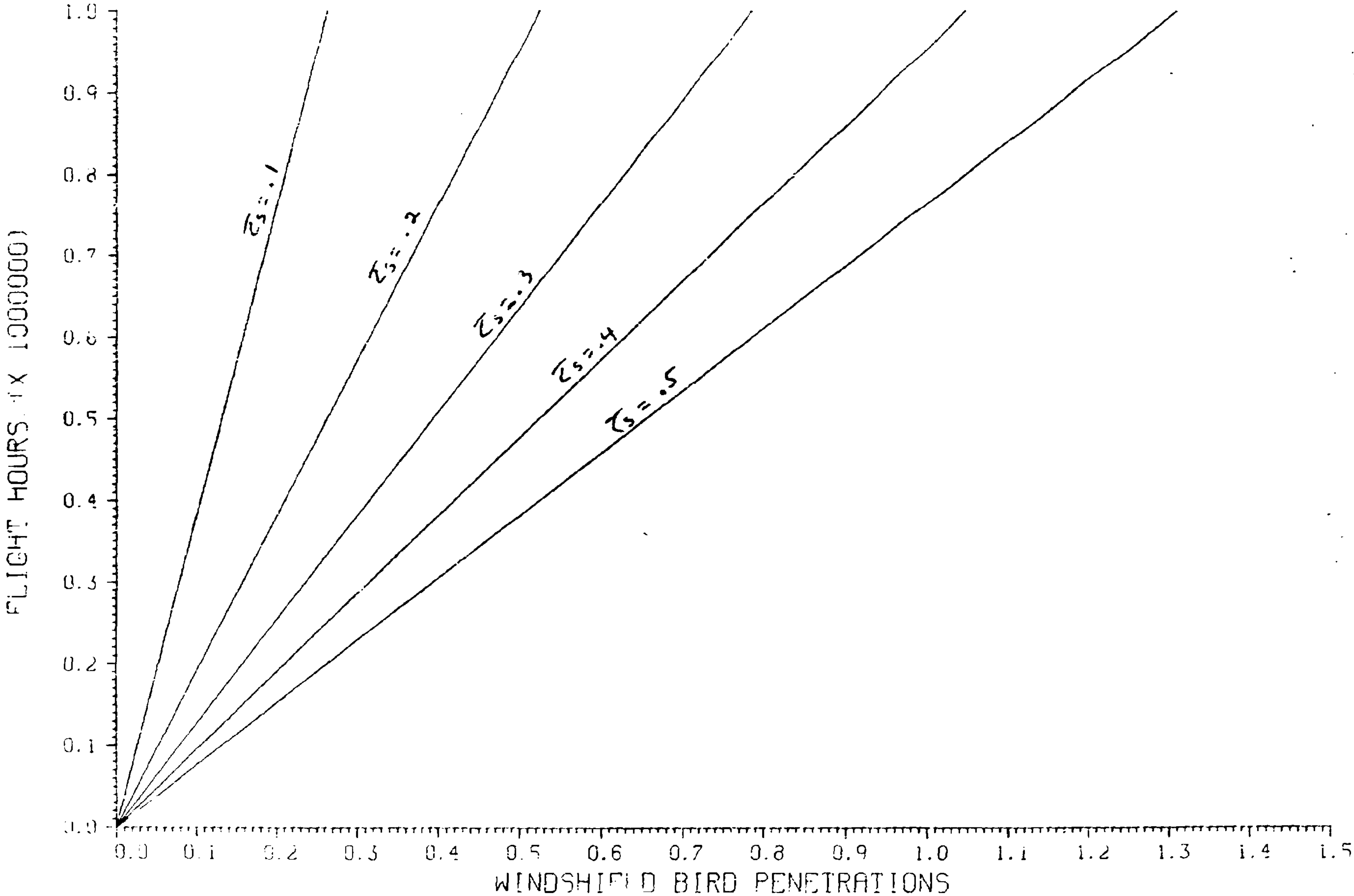


FIG. 49 F-15 DRF, PRESENT WINDSHIELD CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

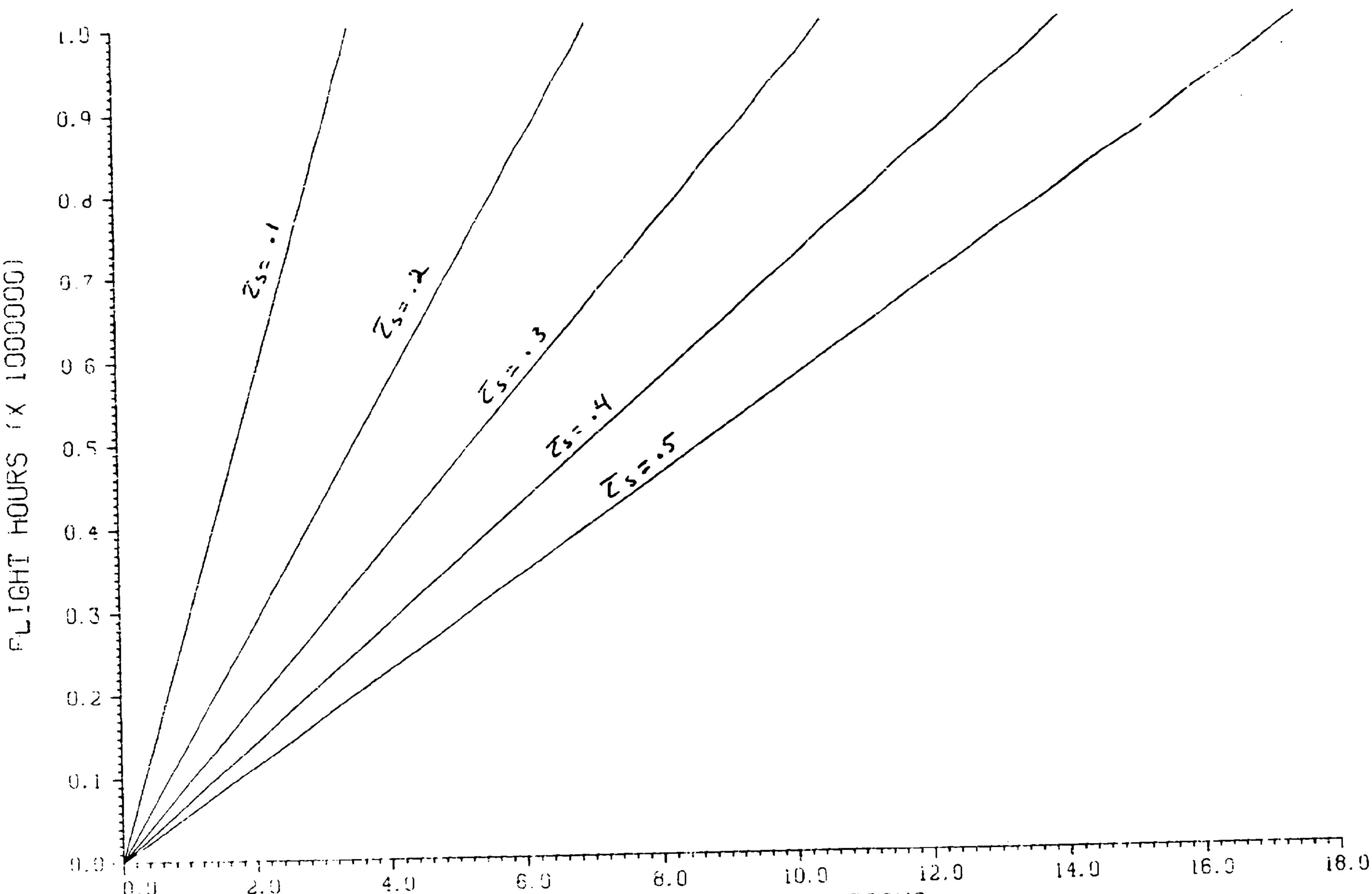


FIG 50 F-15 DRF, PRESENT CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

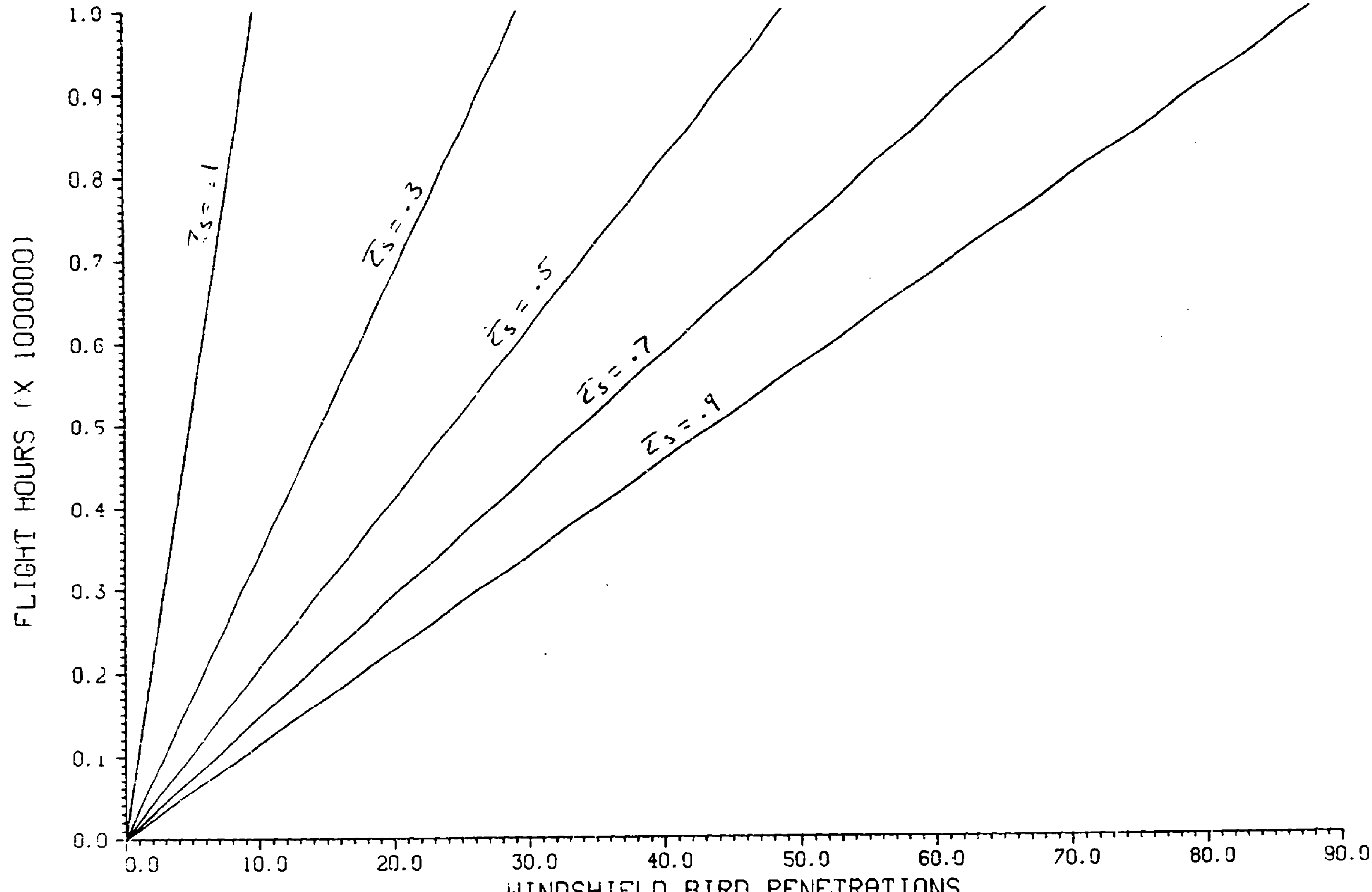


FIG. 51 F-15 DRF, PRESENT WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

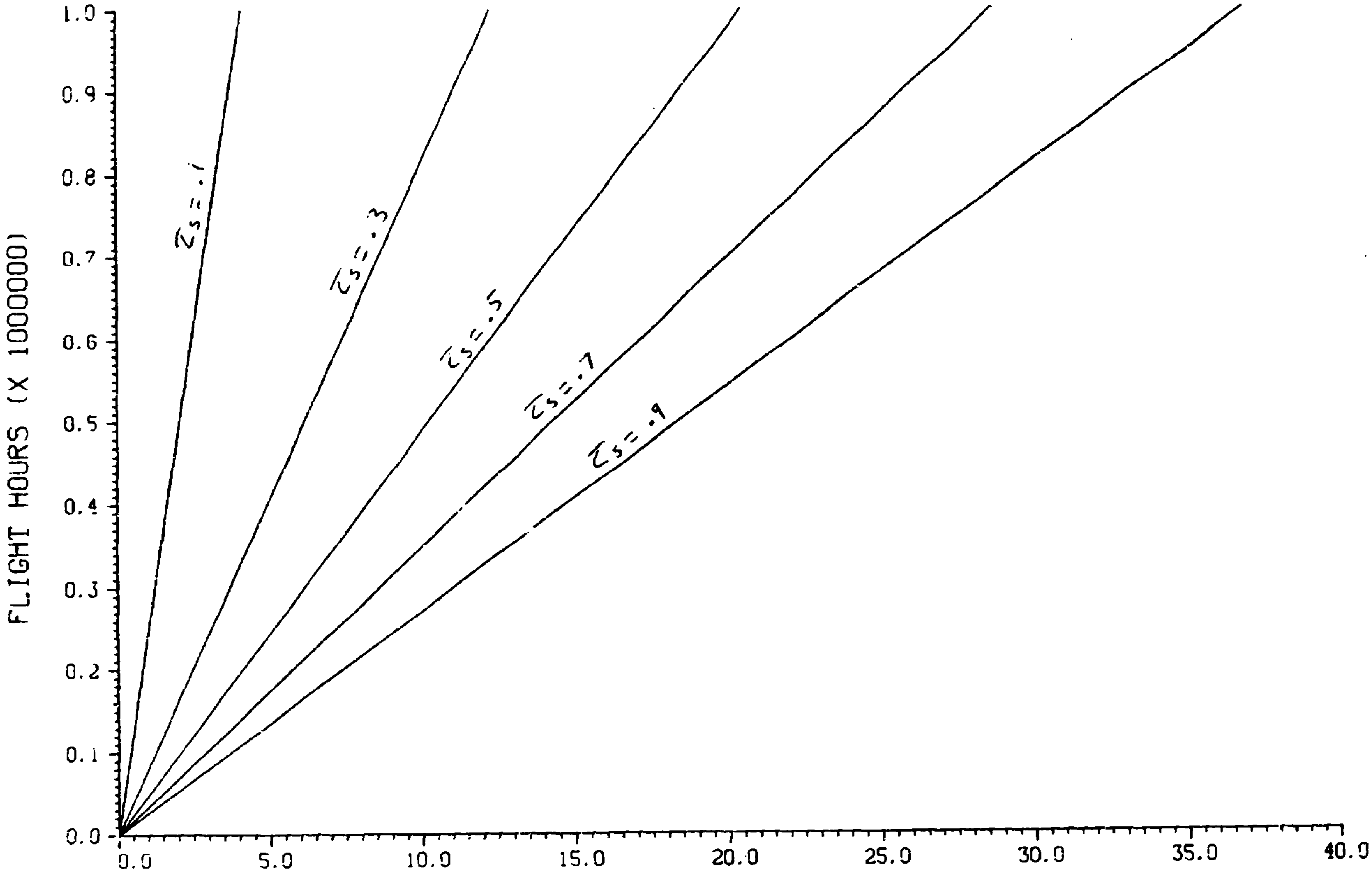
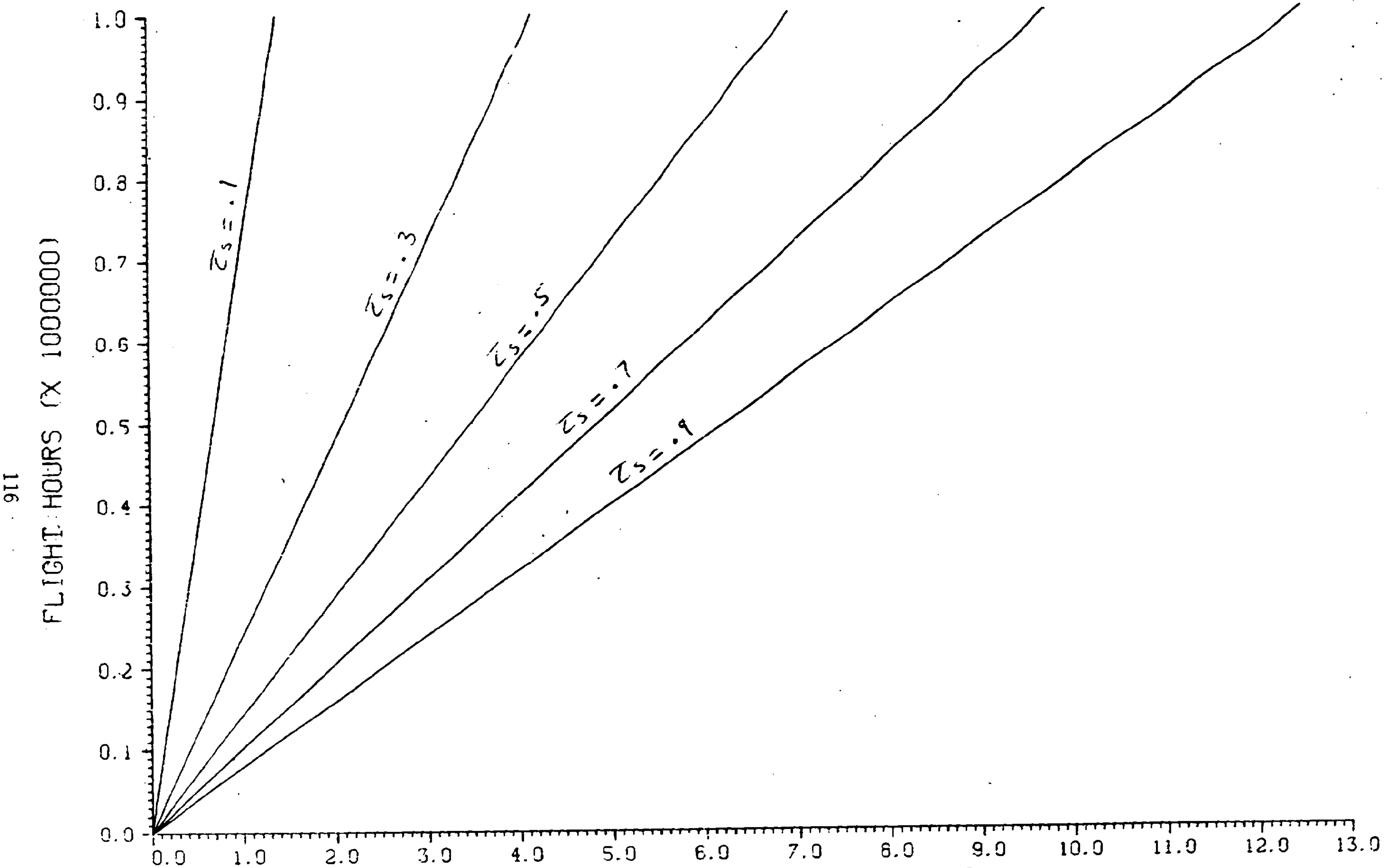


FIG. 52 F-15 DRF, PRESENT CANOPY CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)



WINDSHIELD BIRD PENETRATIONS

FIG. 53 F-15 DRF, PRESENT WINDSHIELD CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

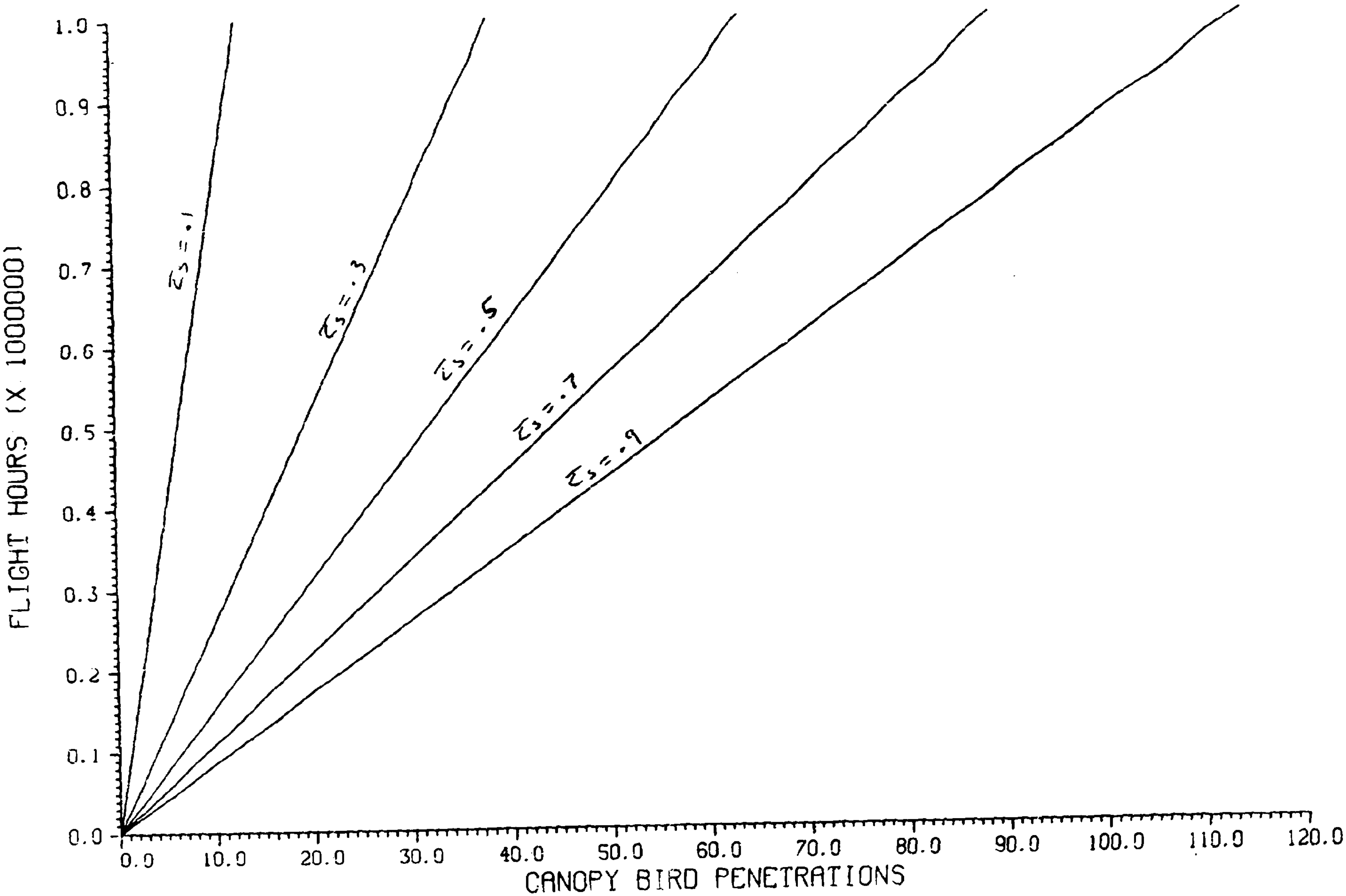


FIG. 54 F-15 DRF, PRESENT CANOPY CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

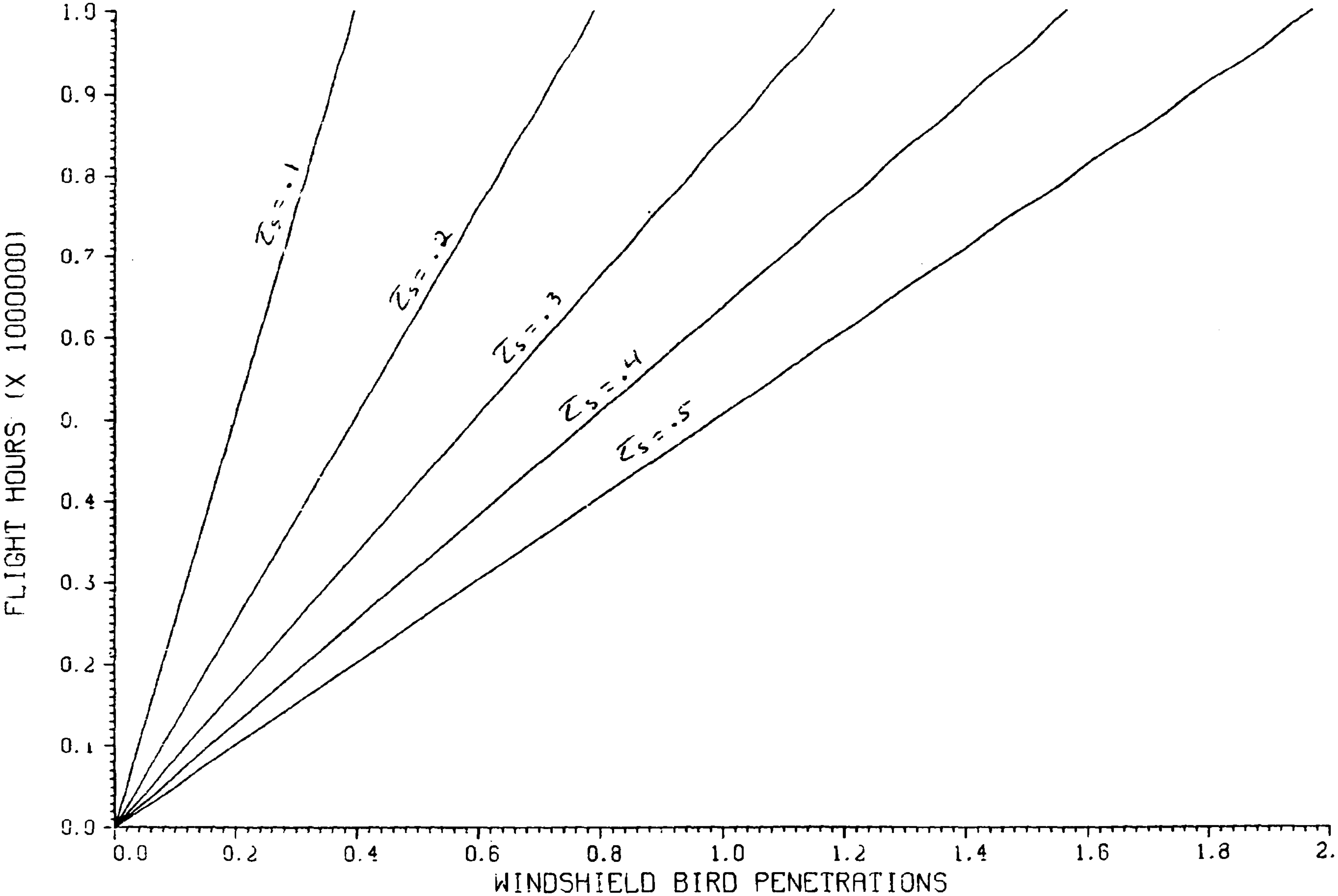


FIG. 55 F-15 DRF, 450 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

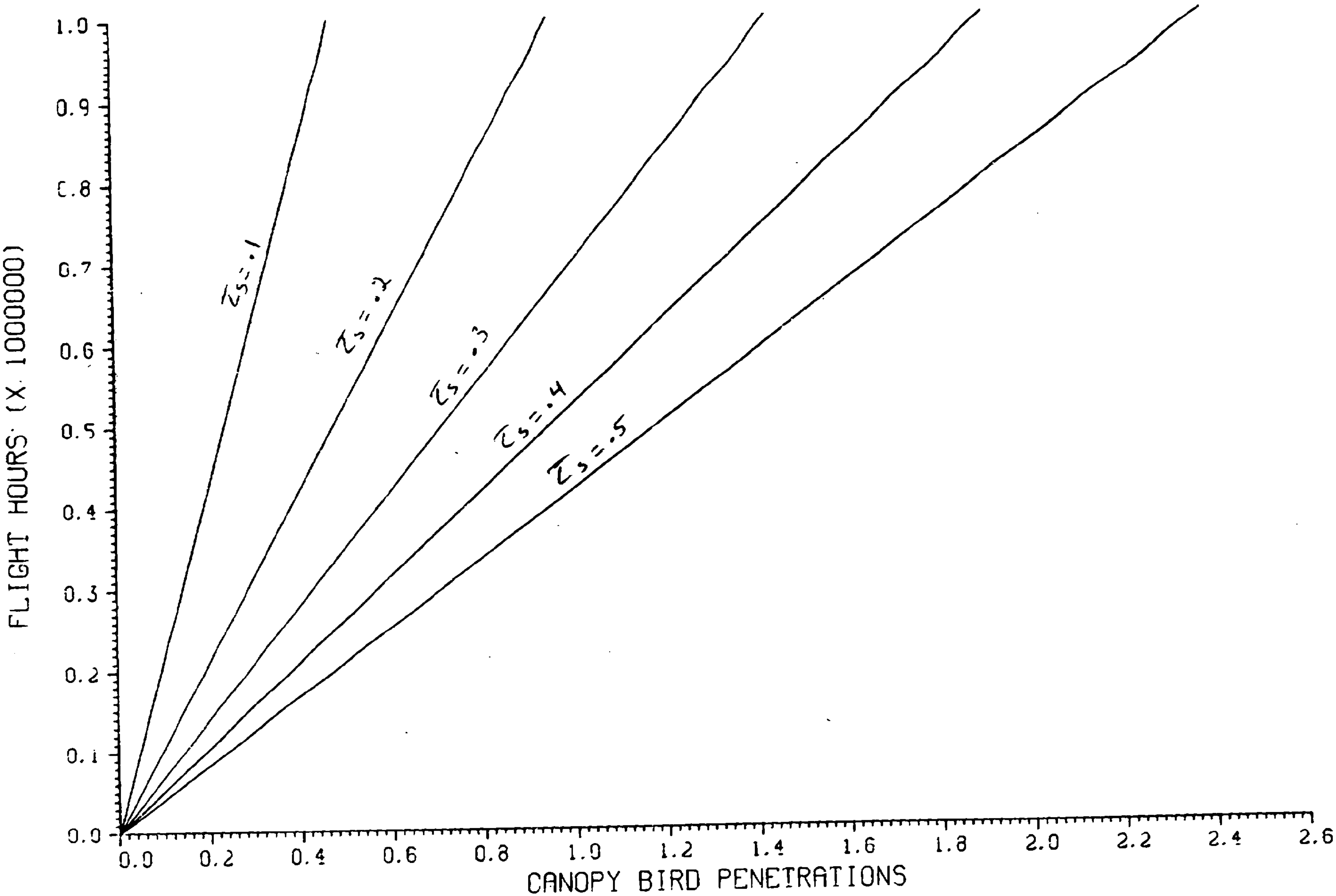


FIG. 56 F-15 DRF, 300 KT. CANOPY CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

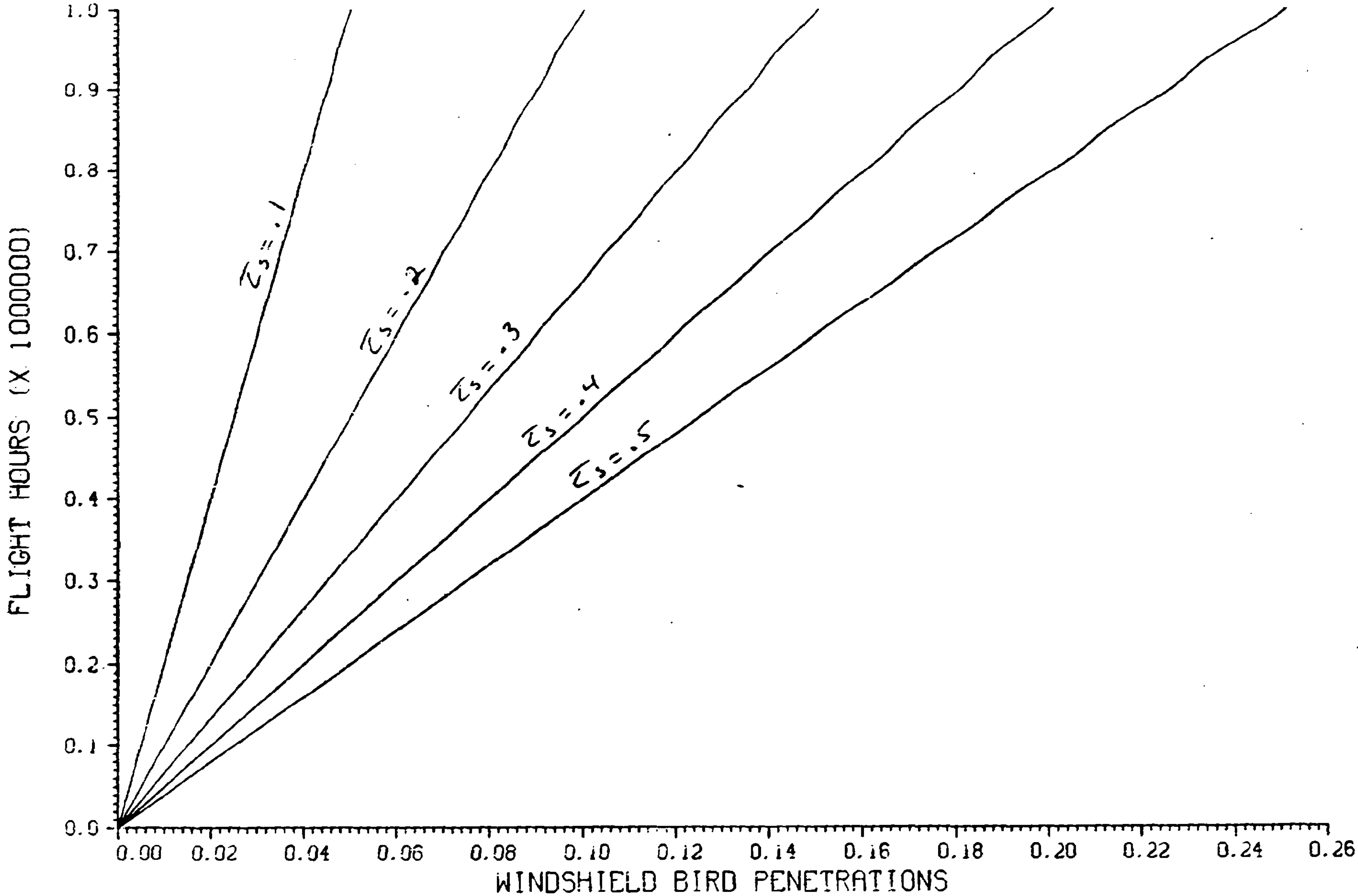


FIG. 57 F-15 DRF, 450 KT. WINDSHIELD CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

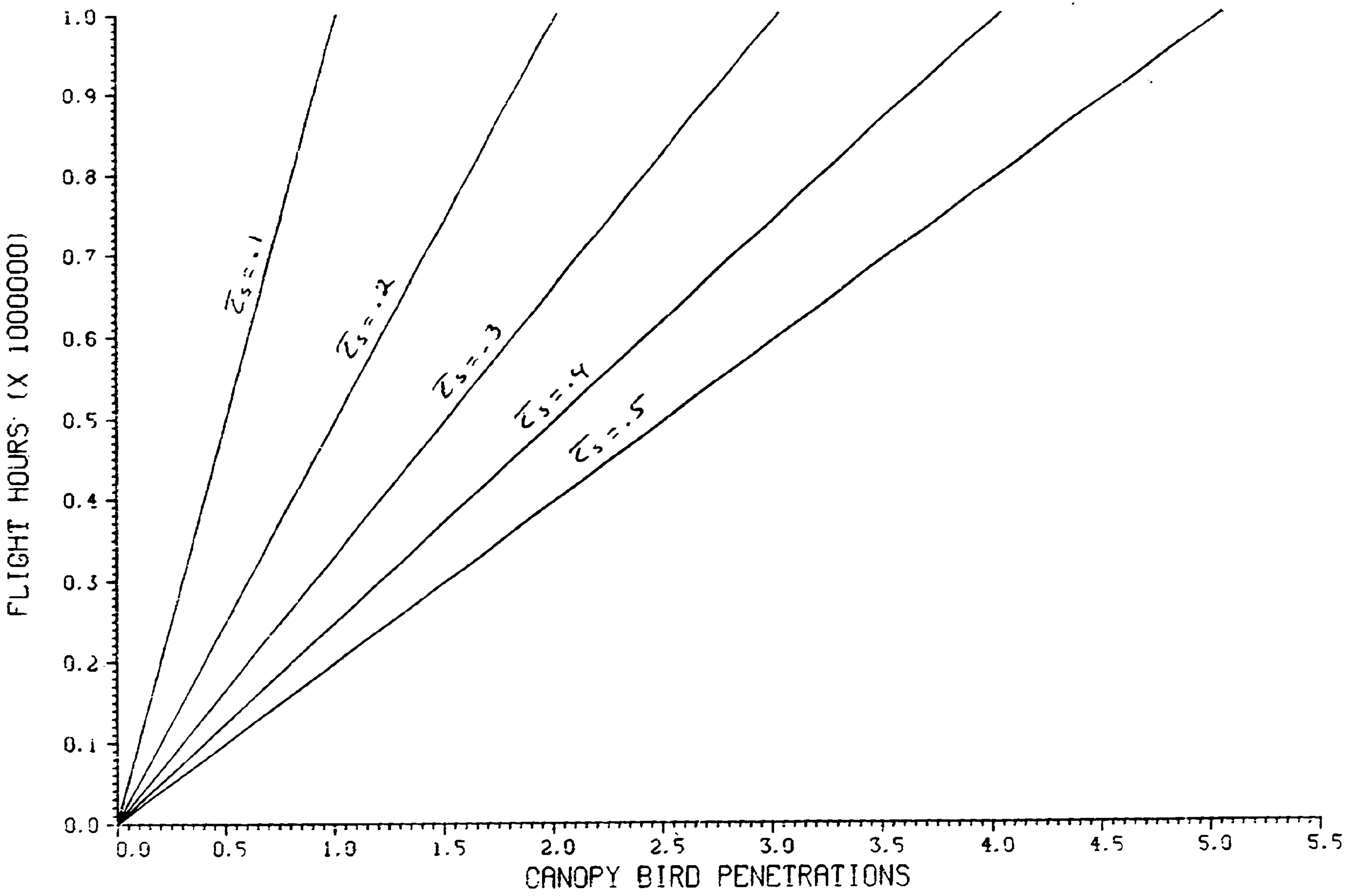


FIG. 58 F-15 DRF, 300 KT. CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

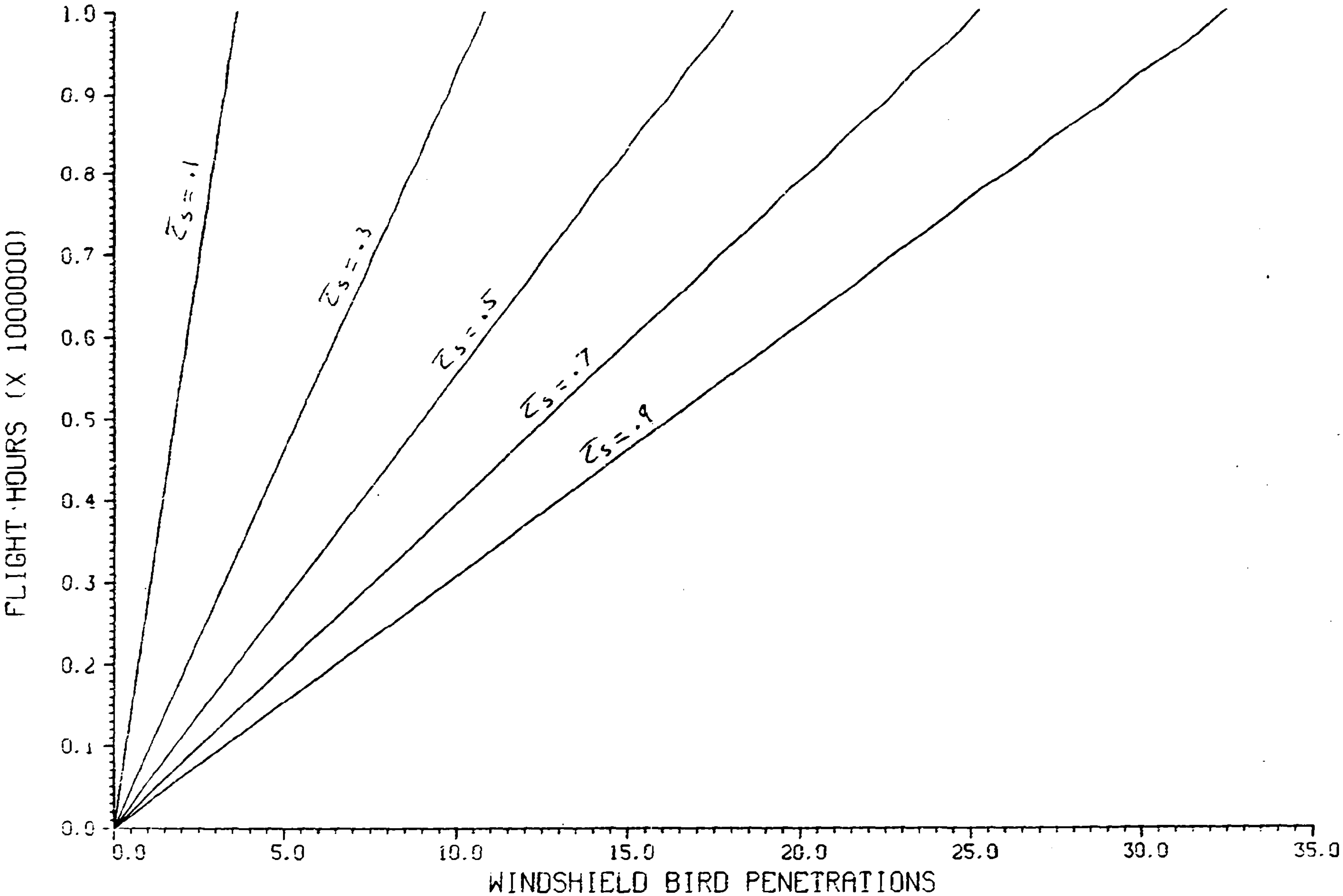


FIG. 59 F-15 DRF, 450 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

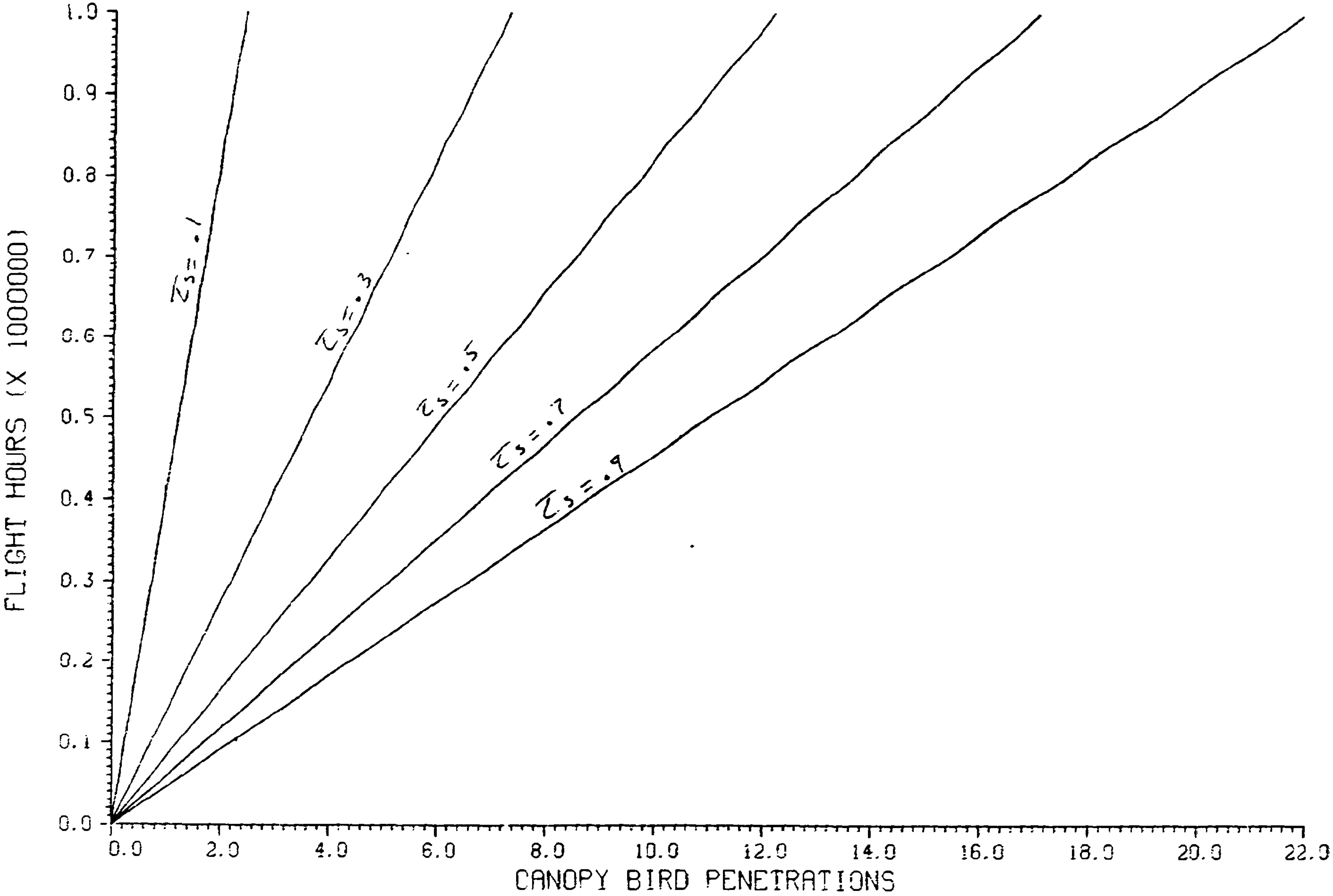


FIG. 60 F-15 DRF, 300 KT. CANOPY CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

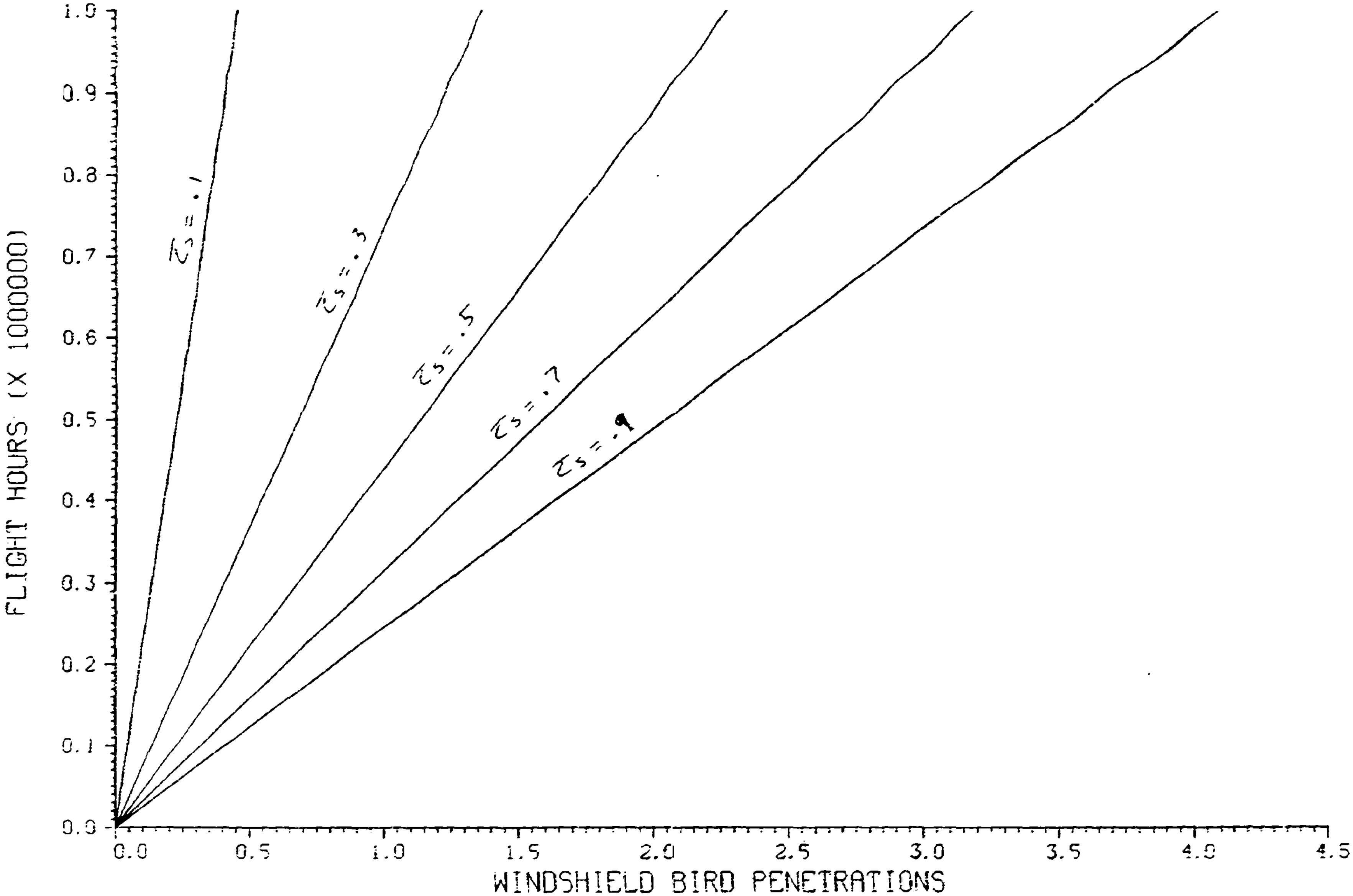


FIG. 61 F-15 DRF, 450 KT. WINDSHIELD CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

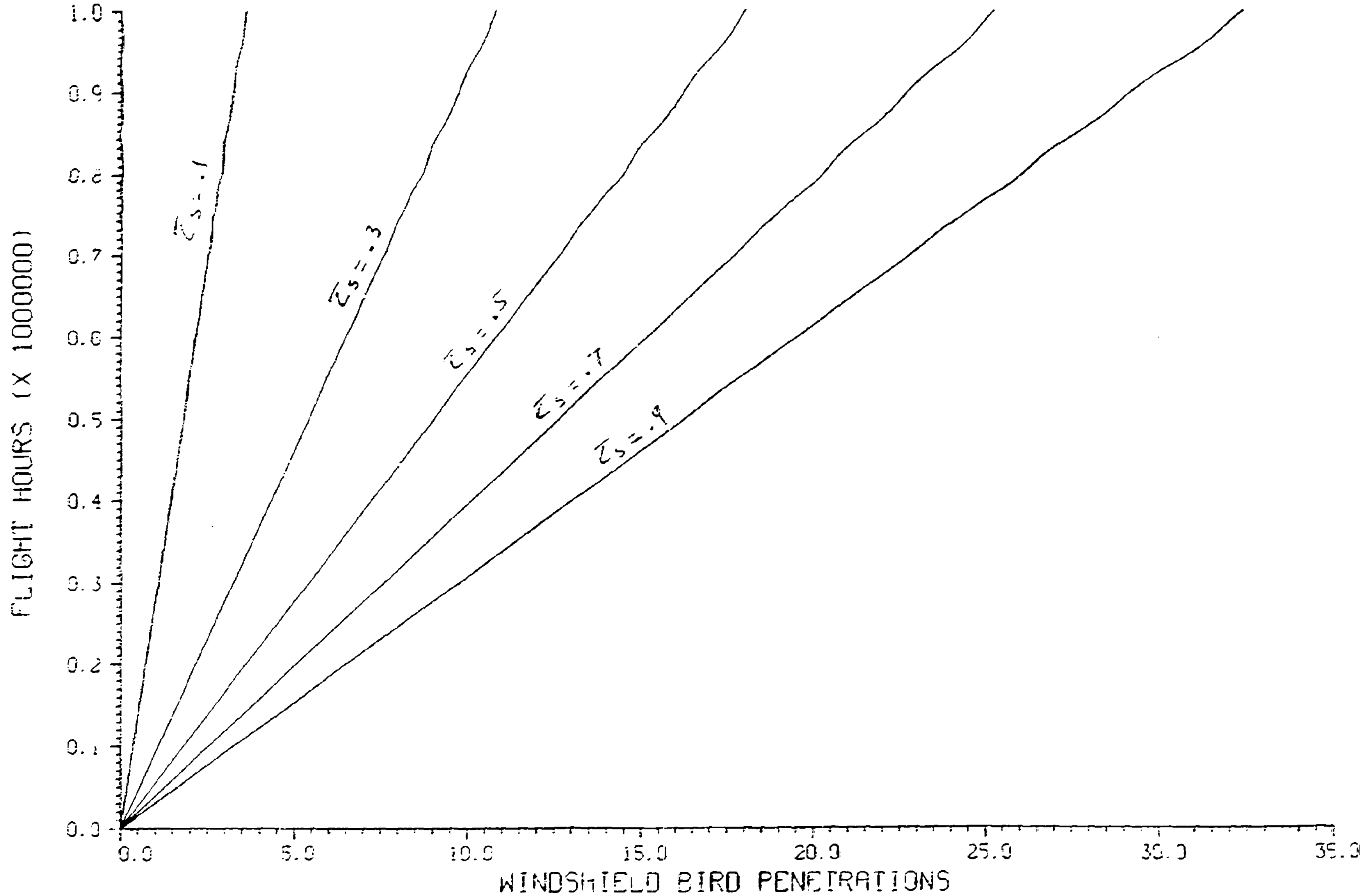


FIG. 62 F-15 DRF, 450 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

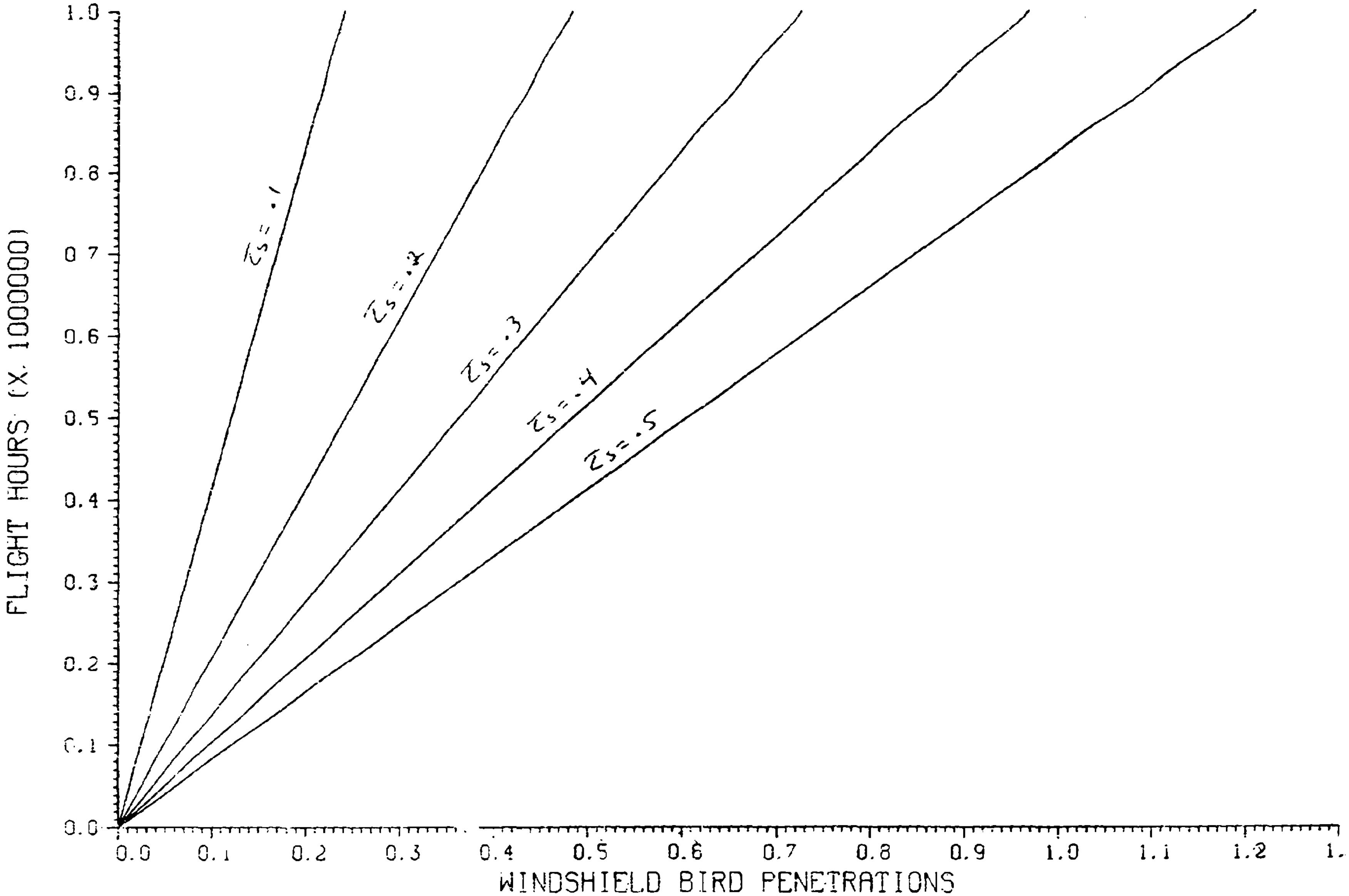


FIG. 63 F-15 DRF, 500 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

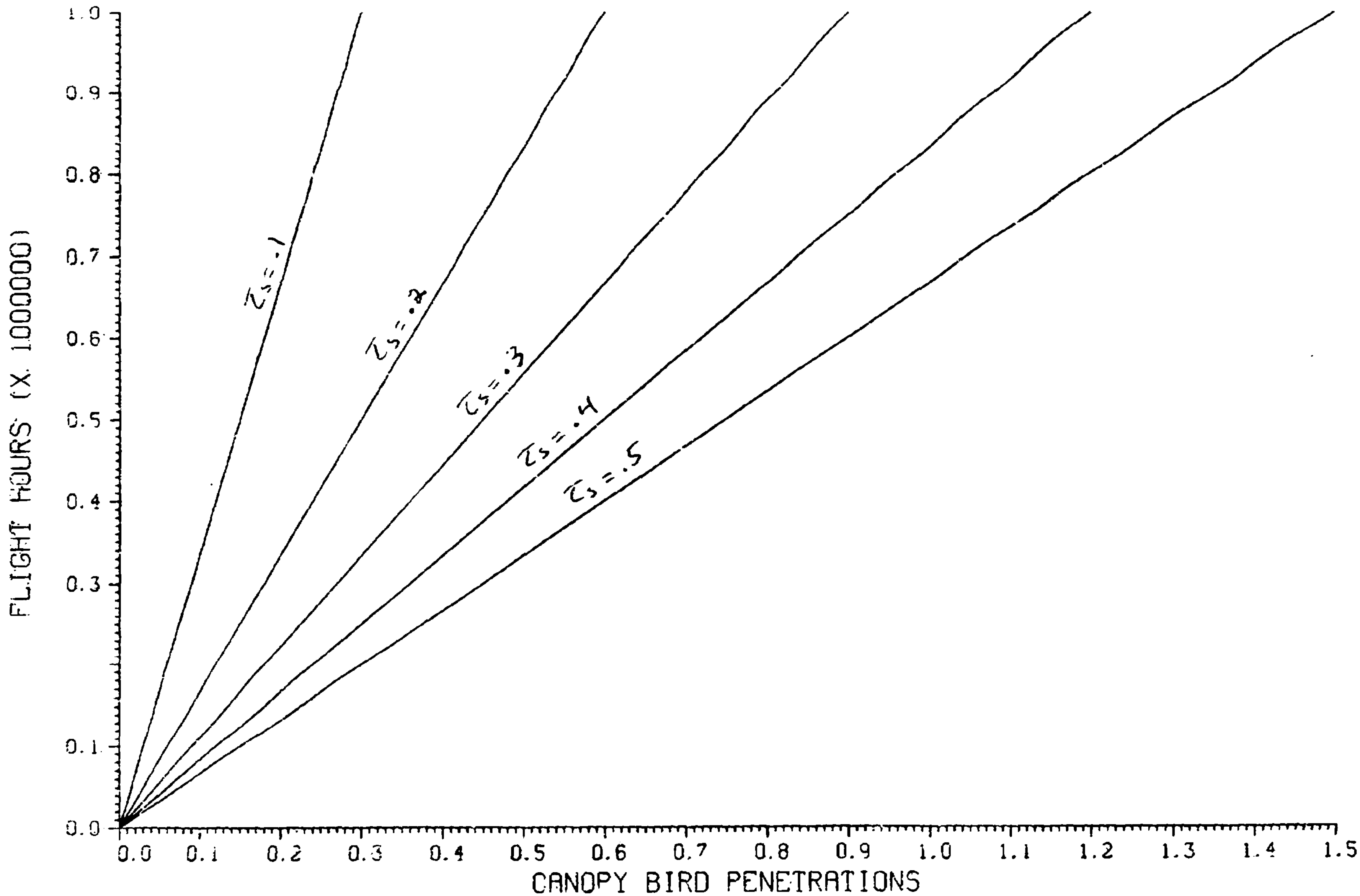


FIG. 64 F-15 DRF, 350 KT. CANOPY CAPABILITY
CONUS, AIR TO AIR (0-5000 FT. AGL)

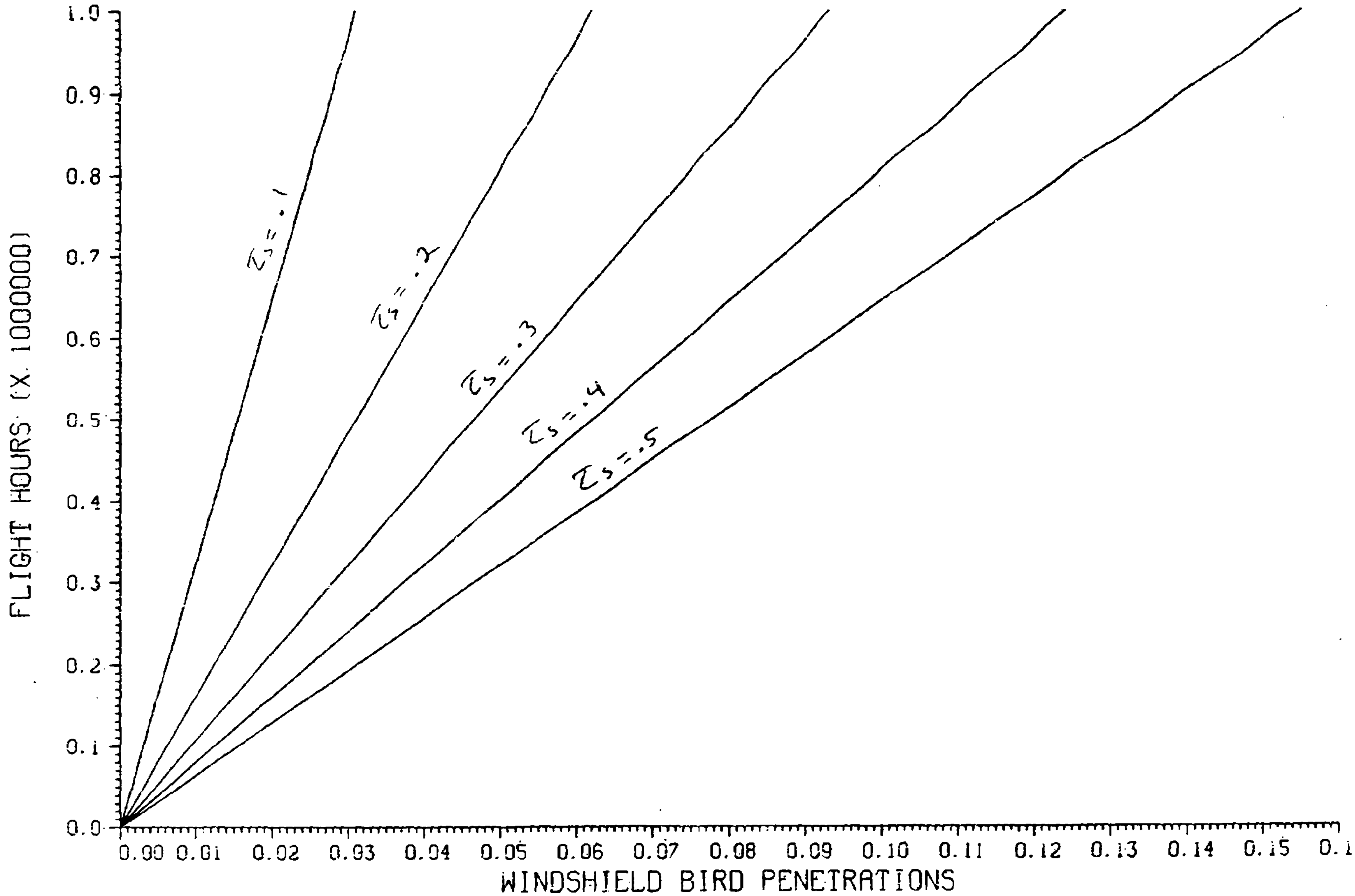


FIG. 65 F-15 DRF, 500 KT. WINDSHIELD CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

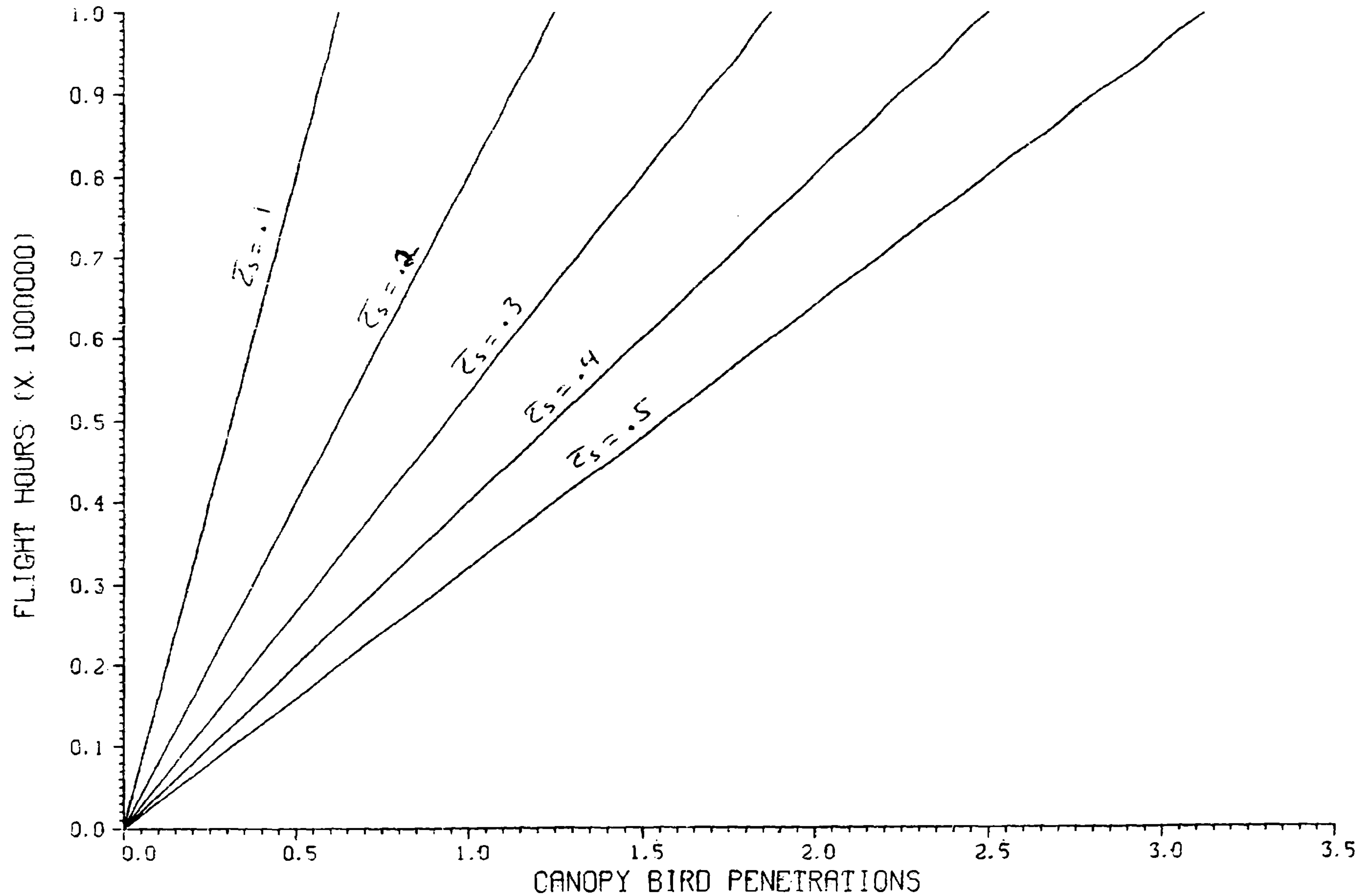


FIG. 66 F-15 DRF, 350 KT. CANOPY CAPABILITY
EUROPE, AIR TO AIR (0-5000 FT. AGL)

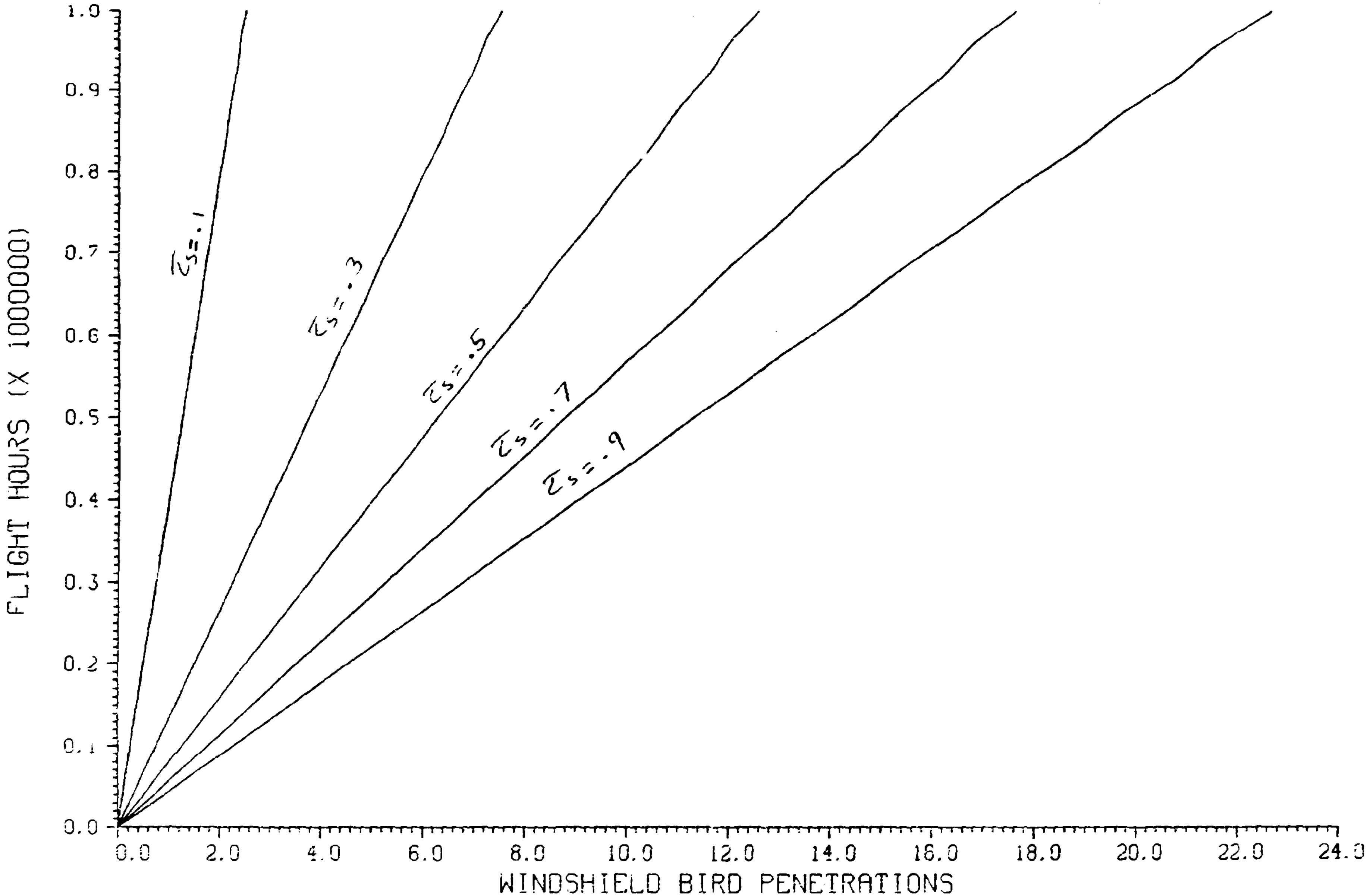


FIG. 67 F-15 DRF, 500 KT. WINDSHIELD CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

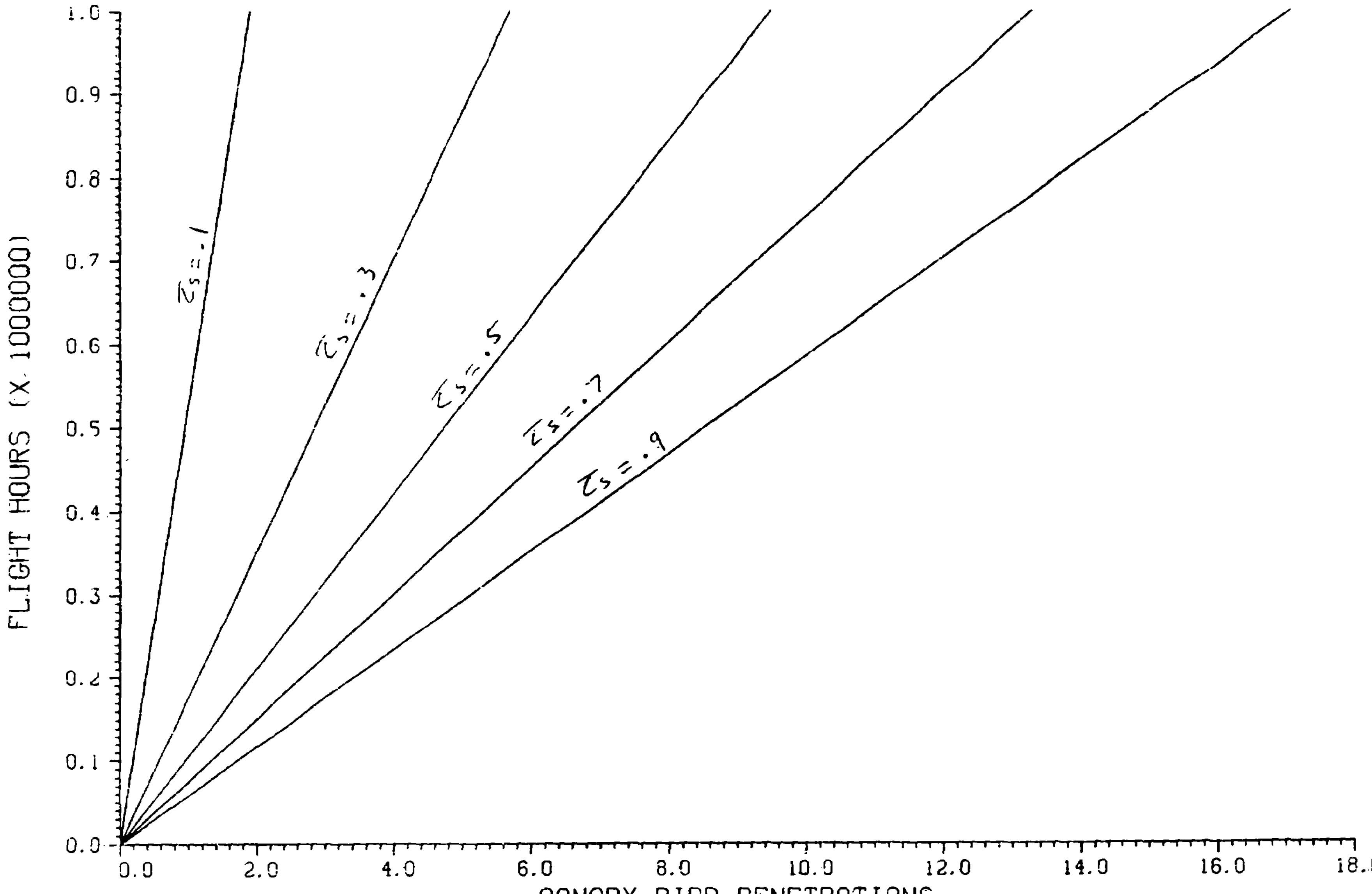


FIG. 68 F-15 DRF, 350 KT. CANOPY CAPABILITY
CONUS, AIR TO GROUND (0-5000 FT. AGL)

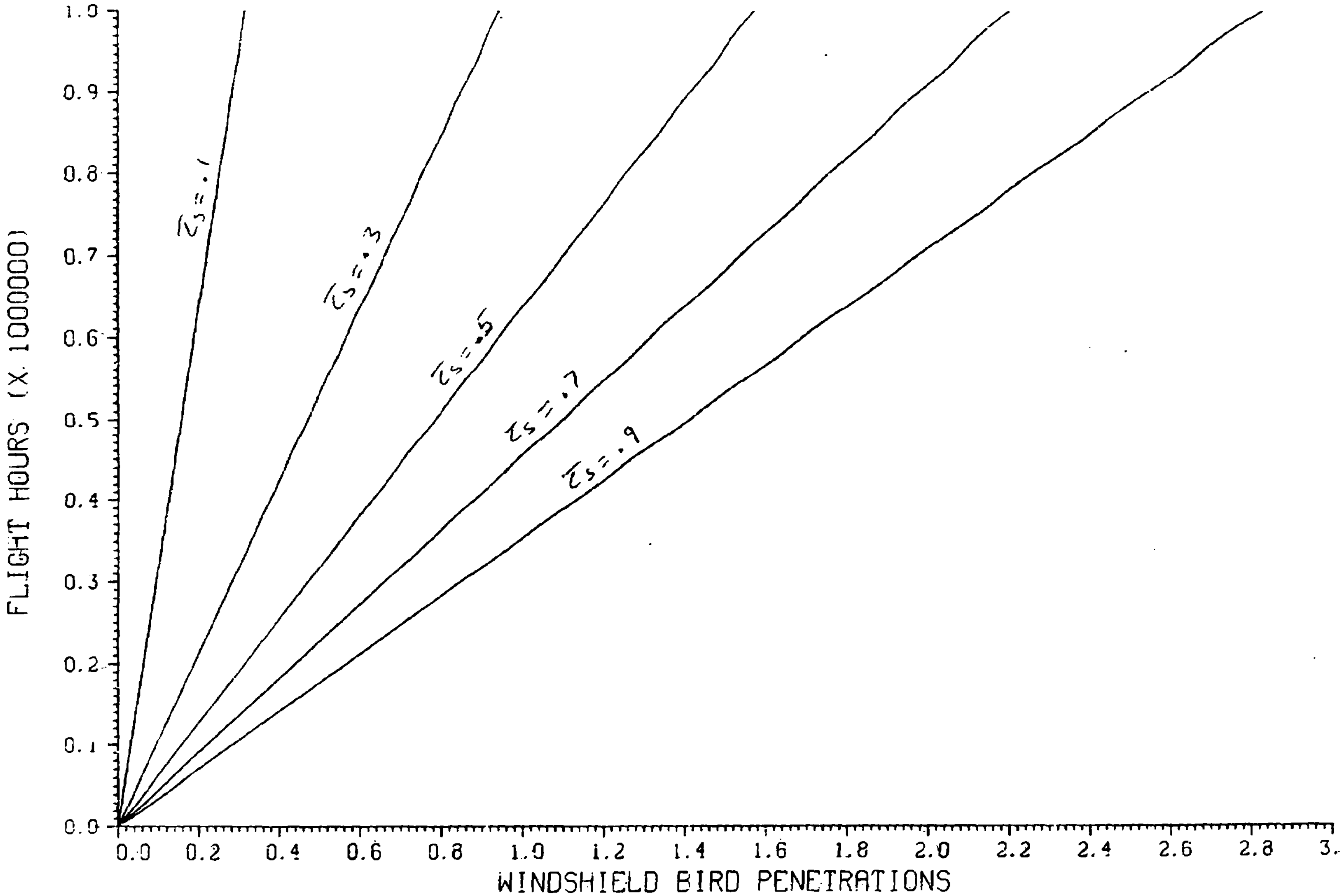


FIG. 69 F-15 DRF, 500 KT. WINDSHIELD CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

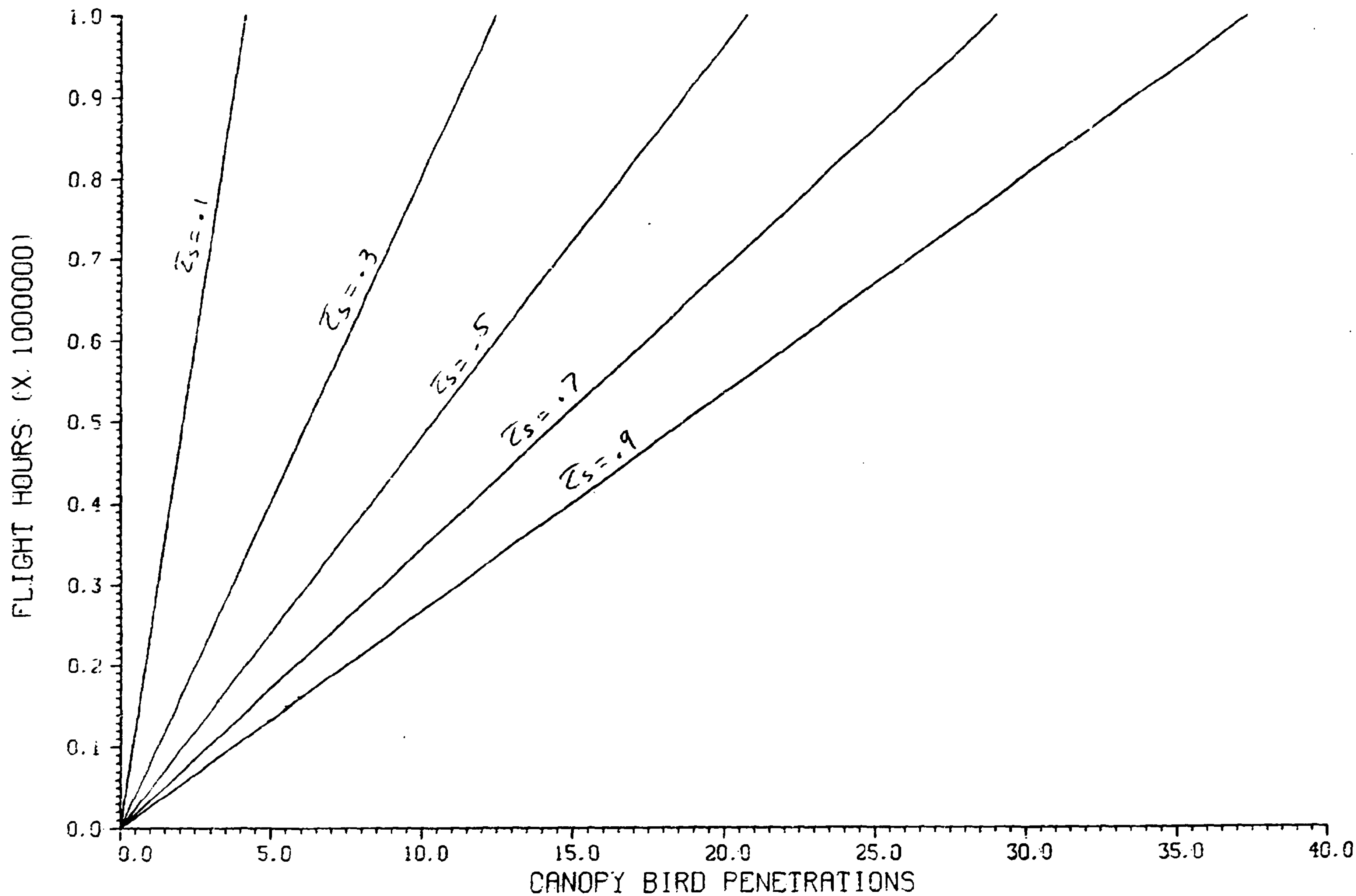


FIG. 70 F-15 DRF, 350 KT. CANOPY CAPABILITY
EUROPE, AIR TO GROUND (0-5000 FT. AGL)

```
      PROGRAM BAAPF(INPUT,OUTPUT)
      DIMENSION PW(15),PWC(15),PWE(15),BWGT(15)
      DIMENSION VEL(12),PV(12),PV1(12),ENOB(12,15)
      DIMENSION ACA(12,15),ACAW(12,15),ACAC(12,15)
      DATA PWC/.5149,.1631,.1074,.0668,.0438,.0295,.0204,.0144,
     1.0103,.0075,.0054,.0040,.0030,.0022,.0017/
      DATA PWE/.7793,.1022,.0449,.0243,.0147,.0094,.0064,.0045,
     1.0032,.0024,.0018,.0014,.0010,.0008,.0007/
      DATA BWGT/.5,1.5,2.5,3.5,4.5,5.5,6.5,7.5,8.5,9.5,10.5,
     111.5,12.5,13.5,14.5/
      DATA VEL/"110-160","160-210","210-260","260-310","310-360",
     1"360-410","410-460","460-510","510-560","560-610",
     1"610-660","660-710"/
      DATA PV1/.0948,.1501,.1950,.2040,.1660,.1080,.0540,.0210,.0060,
     1.0010,0.0,0.0/
C     WINDSHIELD AC/A
      DATA (ACAW(1,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.,0.,
     10.,0.,0.,0.,0.,0.,0./
      DATA (ACAW(2,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.,0.,
     10.,0.,0.,.258,.439,.456,.473/
      DATA (ACAW(3,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.0,.432,
     1.459,.487,.514,.542,1.0,1.0,1.0/
      DATA (ACAW(4,J),J=1,15)/0.,0.,0.,0.,.184,.448,.488,.529,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(5,J),J=1,15)/0.,0.,0.,.256,.477,.533,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(6,J),J=1,15)/0.,0.,.198,.484,.557,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(7,J),J=1,15)/0.,0.,.461,.555,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(8,J),J=1,15)/0.,0.0,.518,1.,1.,1.,1.,1.,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(9,J),J=1,15)/0.,.440,1.0,1.0,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(10,J),J=1,15)/0.,.481,1.0,1.0,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(11,J),J=1,15)/0.,.527,1.0,1.0,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(12,J),J=1,15)/0.0,1.,1.,1.,1.,1.,1.,1.0,
     11.,1.,1.,1.,1.,1.,1./
C     CANOPY AC/A
      DATA (ACAC(1,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.,.207,
     1.302,.398,.493,.588,.684,.779,.805/
      DATA (ACAC(2,J),J=1,15)/0.,0.,0.,0.,.298,.477,.656,.802,
     1.814,.826,.839,.851,.863,.875,.888/
      DATA (ACAC(3,J),J=1,15)/0.,0.,.214,.503,.792,.819,.838,.858,
     1.878,.898,.918,.937,.957,.977,.997/
      DATA (ACAC(4,J),J=1,15)/0.,0.,.554,.812,.841,.870,.899,.928,
     1.957,.986,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(5,J),J=1,15)/0.,.373,.810,.851,.891,.931,.971,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(6,J),J=1,15)/0.,.655,.843,.896,.949,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.00,1.0/
      DATA (ACAC(7,J),J=1,15)/0.,.812,.879,.947,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(8,J),J=1,15)/0.,.836,.921,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(9,J),J=1,15)/.241,.864,.966,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(10,J),J=1,15)/.387,.894,1.0,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
```

```
      DATA (ACAC(11,J),J=1,15)/.547,.927,1.0,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(12,J),J=1,15)/.719,.962,1.0,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
    1 PRINT *,"WINDSHIELD OR CANOPY ? "
      READ 1010,PART
      IF(PART.EQ."WINDSHIELD")GOTO 810
      IF(PART.EQ."CANOPY")GOTO 830
      PRINT *,"PLEASE ENTER 'WINDSHIELD' OR 'CANOPY'"
      GOTO 1
  810 DO 820 I=1,12
      DO 820 J=1,15
  820 ACA(I,J)=ACAW(I,J)
      GOTO 5
  830 DO 840 I=1,12
      DO 840 J=1,15
  840 ACA(I,J)=ACAC(I,J)
    5 PRINT *,"OPERATIONAL IMPACT RATE ( PER 10**6 ) = "
      READ *,OIR
   10 PRINT *,"CONUS OR EUROPE? --- "
      READ 1010,WHERE
      PRINT *,"ENTER FORCE USAGE --- "
      READ *,FU
      IF(WHERE.EQ."CONUS")GOTO 20
      IF(WHERE.EQ."EUROPE")GOTO 40
      PRINT *,"PLEASE ENTER 'CONUS' OR ' EUROPE'"
      GOTO 10
   20 DO 30 I=1,15
   30 PW(I)=PWC(I)
      GOTO 60
   40 DO 50 I=1,15
   50 PW(I)=PWE(I)
   60 PRINT *,"ENTER % F-15 ="
      READ *,P15
      IF(P15.EQ.100.)GOTO 70
      PRINT *,"WARNING THE MIX DID NOT TOTAL 100%"
   70 F15=P15/100.
      DO 80 I=1,12
   80 PV(I)=F15*PV1(I)
      IP15=P15
      PRINT 1020,WHERE,IP15,PART,OIR,FU
      PRINT 1025,BWGT
      DO 100 I=1,12
      DO 90 J=1,15
      ENOB(I,J)=OIR*FU*PV(I)*PW(J)
   90 CONTINUE
  100 PRINT 1030,VEL(I),(ENOB(I,J),J=1,15)
      PRINT 1040
      PRINT 1025,BWGT
      B=0
      DO 120 I=1,12
      DO 110 J=1,15
      ENOB(I,J)=ENOB(I,J)*ACA(I,J)
      B=ENOB(I,J) +B
  110 CONTINUE
  120 PRINT 1030,VEL(I),(ENOB(I,J),J=1,15)
      PRINT 1060,B
 1010 FORMAT(A10)
 1020 FORMAT(1H1,
     1 10X,A10,I3," F-15 MIX (",A10,")",
```

```
     2 //,10X,"OIR =",F10.2," / 10**6   FU = ",F10.4," * 10**6",
     3 ////,25X,"EXPECTED NUMBER OF BIRDSTRIKE (UNCORRECTED)")
 1025 FORMAT(/,3X,"VELOCITY    ",25X,"BIRD WEIGHT (LBS)",
     1 /,3X,"(KNOTS,    ",15F8.3)
 1030 FORMAT(/,3X,A10,15F8.4)
 1040 FORMAT(////,25X,"EXPECTED NUMBER OF BIRDSTRIKES (CORRECTED)")
 1060 FORMAT(/,25X,"THE TOTAL EXPECTED NUMBER OF PENETRATIONS = ",F10.4)
      END
*EOR
```

```
430008   CM STORAGE USED
     .494 CP SECONDS COMPILATION TIME
WINDSHIELD OR CANOPY ?WINDSHIELD
OPERATIONAL IMPACT RATE ( PER 10**6 ) =29.6
CONUS OR EUROPE? ---CONUS
ENTER FORCE USAGE ---.473008
ENTER % F-15 =100

        CONUS     100  F-15 MIX (WINDSHIELD)

        OIR =     29.60 / 10**6   FU =      .4730 * 10**8
```

EXPECTED NUMBER OF BIRDSTRIKE (UNCORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	.6834	.2165	.1426	.0887	.0581	.0382	.0271	.0181	.0137	.0100	.0072	.0053	.0040	.0029	.0023
160-210	1.0821	.3428	.2257	.1404	.0920	.0620	.0429	.0303	.0218	.0158	.0113	.0084	.0083	.0048	.0036
210-260	1.4058	.4453	.2932	.1824	.1186	.0805	.0557	.0393	.0281	.0205	.0147	.0108	.0082	.0080	.0046
260-310	1.4707	.4658	.3068	.1908	.1251	.0843	.0583	.0411	.0294	.0214	.0154	.0114	.0088	.0063	.0049
310-360	1.1967	.3791	.2496	.1553	.1018	.0686	.0474	.0335	.0239	.0174	.0128	.0093	.0070	.0051	.0040
360-410	.7788	.2466	.1824	.1010	.0662	.0446	.0308	.0218	.0156	.0113	.0082	.0060	.0045	.0033	.0028
410-460	.3893	.1233	.0812	.0505	.0331	.0223	.0154	.0108	.0078	.0057	.0041	.0030	.0023	.0017	.0013
460-510	.1514	.0480	.0316	.0196	.0129	.0087	.0060	.0042	.0030	.0022	.0018	.0012	.0009	.0006	.0005
510-560	.0433	.0137	.0090	.0056	.0037	.0025	.0017	.0012	.0008	.0006	.0005	.0003	.0003	.0002	.0001
560-610	.0072	.0023	.0015	.0009	.0006	.0004	.0003	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

APPENDIX B

EXPECTED NUMBER OF BIRDSTRIKES (CORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160-210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0022	.0028	.0021	.0017
210-260	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0170	.0129	.0100	.0078	.0059	.0082	.0080	.0048
260-310	0.0000	0.0000	0.0000	0.0000	.0230	.0377	.0284	.0218	.0294	.0214	.0154	.0114	.0086	.0083	.0049
310-360	0.0000	0.0000	0.0000	.0397	.0486	.0365	.0474	.0335	.0239	.0174	.0128	.0083	.0070	.0051	.0040
360-410	0.0000	0.0000	.0322	.0489	.0369	.0446	.0308	.0218	.0158	.0113	.0082	.0060	.0045	.0033	.0026
410-460	0.0000	0.0000	.0374	.0280	.0331	.0223	.0154	.0109	.0078	.0057	.0041	.0030	.0023	.0017	.0013
460-510	0.0000	0.0000	.0164	.0196	.0129	.0087	.0060	.0042	.0030	.0022	.0018	.0012	.0008	.0006	.0005
510-560	0.0000	.0060	.0090	.0056	.0037	.0025	.0017	.0012	.0009	.0006	.0005	.0003	.0003	.0002	.0001
560-610	0.0000	.0011	.0015	.0009	.0008	.0004	.0003	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

THE TOTAL EXPECTED NUMBER OF PENETRATIONS = 1.1299

END BAAPF
020200 MAXIMUM EXECUTION FL.
0.089 CP SECONDS EXECUTION TIME.

```
43000B   CM STORAGE USED
      .499 CP SECONDS COMPILATION TIME
WINDSHIELD OR CANOPY ?CANOPY
OPERATIONAL IMPACT RATE ( PER 10**6 ) =4.23
CONUS OR EUROPE) ---CONUS
ENTER FORCE USAGE  ---.473008
ENTER % F-15 =100
```

CONUS 100 F-15 MIX (CANOPY)

OIR = 4.23 / 10**6 FU = .4730 * 10**5

EXPECTED NUMBER OF BIRDSTRIKE (UNCORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	.0977	.0309	.0204	.0127	.0083	.0056	.0039	.0027	.0020	.0014	.0010	.0008	.0006	.0004	.0003
160-210	.1546	.0450	.0323	.0201	.0132	.0089	.0061	.0043	.0031	.0023	.0016	.0012	.0009	.0007	.0005
210-260	.2009	.0636	.0419	.0261	.0171	.0115	.0080	.0056	.0040	.0029	.0021	.0016	.0012	.0009	.0007
260-310	.2102	.0655	.0438	.0273	.0179	.0120	.0083	.0059	.0042	.0031	.0022	.0018	.0012	.0009	.0007
310-360	.1710	.0542	.0357	.0222	.0145	.0098	.0068	.0048	.0034	.0025	.0019	.0013	.0010	.0007	.0006
360-410	.1113	.0352	.0232	.0144	.0095	.0064	.0044	.0031	.0022	.0016	.0012	.0009	.0005	.0005	.0004
410-460	.0555	.0175	.0116	.0072	.0047	.0032	.0022	.0016	.0011	.0008	.0006	.0004	.0003	.0002	.0002
460-510	.0216	.0053	.0045	.0028	.0018	.0012	.0009	.0006	.0004	.0003	.0002	.0002	.0001	.0001	.0001
510-560	.0062	.0020	.0013	.0008	.0005	.0004	.0002	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000
560-610	.0010	.0003	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

EXPECTED NUMBER OF BIRDSTRIKES (CORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0006	.0006	.0006	.0005	.0004	.0004	.0003	.0003
160-210	0.0000	0.0000	0.0000	0.0000	.0035	.0042	.0040	.0035	.0025	.0019	.0014	.0010	.0008	.0006	.0005
[illegible]	0.0000	0.0000	.0090	.0131	.0135	.0094	.0067	.0048	.0035	.0026	.0019	.0015	.0011	.0008	.0007
260-310	0.0000	0.0000	.0243	.0221	.0150	.0105	.0075	.0055	.0040	.0030	.0022	.0016	.0012	.0009	.0007
310-360	0.0000	.0202	.0289	.0189	.0130	.0091	.0066	.0048	.0034	.0025	.0018	.0013	.0010	.0007	.0006
360-410	0.0000	.0231	.0196	.0129	.0090	.0064	.0044	.0031	.0022	.0016	.0012	.0009	.0006	.0005	.0004
410-460	0.0000	.0143	.0102	.0068	.0047	.0032	.0022	.0016	.0011	.0008	.0006	.0004	.0003	.0002	.0002
460-510	0.0000	.0057	.0042	.0028	.0018	.0012	.0008	.0006	.0004	.0003	.0002	.0002	.0001	.0001	.0001
510-560	.0015	.0017	.0012	.0008	.0005	.0004	.0002	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000
560-610	.0004	.0003	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

THE TOTAL EXPECTED NUMBER OF PENETRATIONS = .4673

```
END  BAAPF
020200 MAXIMUM EXECUTION FL.
 0.078 CP SECONDS EXECUTION TIME.
```

```
 43000B   CM STORAGE USED
     .487 CP SECONDS COMPILATION TIME
WINDSHIELD OR CANOPY ?WINDSHIELD
OPERATIONAL IMPACT RATE ( PER 10**6 ) =21.87
CONUS OR EUROPE? ---EUROPE
ENTER FORCE USAGE ---.136576
ENTER % F-15 =100
```

EUROPE   100   F-15 MIX (WINDSHIELD)

DIR =   21.87 / 10**6   FU =   .1366 * 10**6

EXPECTED NUMBER OF BIRDSTRIKE (UNCORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	.2217	.0281	.0128	.0069	.0042	.0027	.0018	.0013	.0009	.0007	.0005	.0004	.0003	.0002	.0002
160-210	.3510	.0480	.0202	.0109	.0066	.0042	.0028	.0020	.0014	.0011	.0008	.0006	.0005	.0004	.0003
210-260	.4560	.0598	.0263	.0142	.0086	.0055	.0037	.0026	.0018	.0014	.0011	.0008	.0006	.0005	.0004
260-310	.4770	.0626	.0275	.0149	.0090	.0058	.0039	.0028	.0020	.0015	.0011	.0009	.0006	.0005	.0004
310-360	.3882	.0509	.0224	.0121	.0073	.0047	.0032	.0022	.0016	.0012	.0009	.0007	.0005	.0004	.0003
360-410	.2525	.0331	.0146	.0079	.0048	.0030	.0021	.0015	.0010	.0008	.0006	.0005	.0003	.0003	.0002
410-460	.1263	.0166	.0073	.0039	.0024	.0015	.0010	.0007	.0005	.0004	.0003	.0002	.0002	.0001	.0001
460-510	.0491	.0064	.0028	.0015	.0009	.0006	.0004	.0003	.0002	.0002	.0001	.0001	.0001	.0001	.0000
510-560	.0140	.0018	.0008	.0004	.0003	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000
560-610	.0023	.0003	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

EXPECTED NUMBER OF BIRDSTRIKES (CORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
160-210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0002	.0002	.0002	.0001
210-260	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0011	.0009	.0007	.0005	.0004	.0006	.0005	.0004
260-310	0.0000	0.0000	0.0000	0.0000	.0017	.0026	.0019	.0015	.0020	.0015	.0011	.0009	.0008	.0005	.0004
310-360	0.0000	0.0000	0.0000	.0031	.0035	.0025	.0032	.0022	.0018	.0012	.0009	.0007	.0005	.0004	.0003
360-410	0.0000	0.0000	.0029	.0038	.0027	.0030	.0021	.0015	.0010	.0008	.0006	.0005	.0003	.0003	.0002
410-460	0.0000	0.0000	.0034	.0022	.0024	.0015	.0010	.0007	.0005	.0004	.0003	.0002	.0002	.0001	.0001
460-510	0.0000	0.0000	.0015	.0015	.0009	.0006	.0004	.0003	.0002	.0002	.0001	.0001	.0001	.0001	.0000
510-560	0.0000	.0008	.0008	.0004	.0003	.0002	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000
560-610	0.0000	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

THE TOTAL EXPECTED NUMBER OF PENETRATIONS = .0824

END BAAPF
020200 MAXIMUM EXECUTION FL.
0.084 CP SECONDS EXECUTION TIME.

```
430008   CM STORAGE USED
     .506 CP SECONDS COMPILATION TIME
WINDSHIELD OR CANOPY ?CANOPY
OPERATIONAL IMPACT RATE ( PER 10**6 ) =51.25
CONUS OR EUROPE? ---EUROPE
ENTER FORCE USAGE ---.136578
ENTER % F-15 =100
```

EUROPE   100   F-15 MIX (CANOPY   )

OIR =   51.25 / 10**6   FU =   .1366 * 10**6

EXPECTED NUMBER OF BIRDSTRIKE (UNCORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	.5171	.0878	.0298	.0181	.0098	.0062	.0042	.0030	.0021	.0016	.0012	.0008	.0007	.0005	.0005
160-210	.8188	.1074	.0472	.0255	.0154	.0089	.0067	.0047	.0034	.0025	.0018	.0015	.0011	.0008	.0007
210-260	1.0637	.1383	.0613	.0332	.0201	.0128	.0087	.0061	.0044	.0033	.0025	.0018	.0014	.0011	.0010
260-310	1.1128	.1458	.0641	.0347	.0210	.0134	.0081	.0064	.0048	.0034	.0026	.0020	.0014	.0011	.0010
310-360	.9055	.1187	.0522	.0282	.0171	.0108	.0074	.0052	.0037	.0028	.0021	.0016	.0012	.0009	.0008
360-410	.5891	.0773	.0338	.0184	.0111	.0071	.0048	.0034	.0024	.0018	.0014	.0011	.0008	.0006	.0005
410-460	.2946	.0386	.0170	.0092	.0056	.0036	.0024	.0017	.0012	.0008	.0007	.0005	.0004	.0003	.0003
460-510	.1145	.0150	.0066	.0036	.0022	.0014	.0009	.0007	.0005	.0004	.0003	.0002	.0001	.0001	.0001
510-560	.0327	.0043	.0019	.0010	.0006	.0004	.0003	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000
560-610	.0055	.0007	.0003	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

EXPECTED NUMBER OF BIRDSTRIKES (CORRECTED)

VELOCITY (KNOTS)	BIRD WEIGHT (LBS) .500	1.500	2.500	3.500	4.500	5.500	6.500	7.500	8.500	9.500	10.500	11.500	12.500	13.500	14.500
110-160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0006	.0006	.0006	.0006	.0005	.0005	.0004	.0004
160-210	0.0000	0.0000	0.0000	0.0000	.0046	.0047	.0044	.0038	.0027	.0021	.0016	.0013	.0009	.0007	.0007
210-260	0.0000	0.0000	.0131	.0167	.0159	.0105	.0073	.0053	.0038	.0029	.0023	.0018	.0013	.0011	.0010
260-310	0.0000	0.0000	.0355	.0282	.0177	.0117	.0082	.0060	.0044	.0034	.0026	.0020	.0014	.0011	.0010
310-360	0.0000	.0443	.0423	.0240	.0152	.0102	.0072	.0052	.0037	.0028	.0021	.0018	.0012	.0009	.0008
360-410	0.0000	.0506	.0286	.0165	.0105	.0071	.0048	.0034	.0024	.0018	.0014	.0011	.0008	.0006	.0005
410-460	0.0000	.0314	.0149	.0087	.0056	.0036	.0024	.0017	.0012	.0009	.0007	.0005	.0004	.0003	.0003
460-510	0.0000	.0128	.0061	.0036	.0022	.0014	.0009	.0007	.0005	.0004	.0003	.0002	.0001	.0001	.0001
510-560	.0079	.0037	.0018	.0010	.0006	.0004	.0003	.0002	.0001	.0001	.0001	.0001	.0000	.0000	.0000
560-610	.0021	.0006	.0003	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
610-660	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
660-710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

THE TOTAL EXPECTED NUMBER OF PENETRATIONS = .6509

END BAAPF
020200 MAXIMUM EXECUTION FL.
0.071 CP SECONDS EXECUTION TIME.

APPENDIX C

```
      PROGRAM RAAPF(INPUT,OUTPUT)
      DIMENSION PW(15),PWC(15),PWE(15),BWGT(15)
      DIMENSION VEL(12),PV(12),PV1(12),ENOB(12,15)
      DIMENSION ACA(12,15),ACAW(12,15),ACAC(12,15)
      DATA PWC/.5149,.1631,.1074,.0668,.0438,.0295,.0204,.0144,
     1.0103,.0075,.0054,.0040,.0030,.0022,.0017/
      DATA PWE/.7793,.1022,.0449,.0243,.0147,.0094,.0064,.0045,
     1.0032,.0024,.0018,.0014,.0010,.0008,.0007/
      DATA BWGT/.5,1.5,2.5,3.5,4.5,5.5,6.5,7.5,8.5,9.5,10.5,
     111.5,12.5,13.5,14.5/
      DATA VEL/"110-160","160-210","210-260","260-310","310-360",
     1"360-410","410-460","460-510","510-560","560-610",
     1"610-660","660-710"/
      DATA PV1/.0948,.1501,.1950,.2040,.1680,.1080,.0540,.0210,.0060,
     1.0010,0.0,0.0/
C     WINDSHIELD AC/A
      DATA (ACAW(1,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.,0.,
     10.,0.,0.,0.,0.,0.,0./
      DATA (ACAW(2,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.,0.,
     10.,0.,0.,.258,.438,.456,.473/
      DATA (ACAW(3,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.0,.432,
     1.459,.487,.514,.542,1.0,1.0,1.0/
      DATA (ACAW(4,J),J=1,15)/0.,0.,0.,0.,.184,.448,.488,.529,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(5,J),J=1,15)/0.,0.,0.,.256,.477,.533,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(6,J),J=1,15)/0.,0.,.198,.484,.557,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(7,J),J=1,15)/0.,0.,.461,.555,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(8,J),J=1,15)/0.,0.0,.519,1.,1.,1.,1.,1.,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(9,J),J=1,15)/0.,.440,1.0,1.0,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(10,J),J=1,15)/0.,.481,1.0,1.0,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(11,J),J=1,15)/0.,.527,1.0,1.0,1.0,1.0,1.0,1.0,
     11.,1.,1.,1.,1.,1.,1./
      DATA (ACAW(12,J),J=1,15)/0.0,1.,1.,1.,1.,1.,1.,1.0,
     11.,1.,1.,1.,1.,1.,1./
C     CANOPY AC/A
      DATA (ACAC(1,J),J=1,15)/0.,0.,0.,0.,0.,0.,0.,.207,
     1.302,.398,.493,.588,.684,.779,.805/
      DATA (ACAC(2,J),J=1,15)/0.,0.,0.,0.,.298,.477,.658,.802,
     1.814,.826,.838,.851,.863,.875,.888/
      DATA (ACAC(3,J),J=1,15)/0.,0.,.214,.503,.792,.819,.838,.858,
     1.878,.898,.918,.937,.957,.977,.997/
      DATA (ACAC(4,J),J=1,15)/0.,0.,.554,.812,.841,.870,.899,.928,
     1.957,.986,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(5,J),J=1,15)/0.,.373,.810,.851,.891,.931,.971,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(6,J),J=1,15)/0.,.655,.843,.896,.949,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.00,1.0/
      DATA (ACAC(7,J),J=1,15)/0.,.812,.879,.947,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(8,J),J=1,15)/0.,.838,.921,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(9,J),J=1,15)/.241,.864,.986,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(10,J),J=1,15)/.387,.894,1.0,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
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      DATA (ACAC(11,J),J=1,15)/.547,.927,1.0,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
      DATA (ACAC(12,J),J=1,15)/.719,.962,1.0,1.0,1.0,1.0,1.0,1.0,
     11.0,1.0,1.0,1.0,1.0,1.0,1.0/
    1 PRINT *,"WINDSHIELD OR CANOPY (W OR C) ? -"
      READ 1010,PART
      IF(PART.EQ."W")GOTO 810
      IF(PART.EQ."C")GOTO 830
      PRINT *,"PLEASE ENTER 'W' FOR WINDSHIELD OR 'C' FOR CANOPY'"
      GOTO 1
  810 DO 820 I=1,12
      DO 820 J=1,15
  820 ACA(I,J)=ACAW(I,J)
      GOTO 5
  830 DO 840 I=1,12
      DO 840 J=1,15
  840 ACA(I,J)=ACAC(I,J)
    5 PRINT *,"OPERATIONAL IMPACT RATE ( PER 10**6 ) = "
      READ *,OIR
   10 PRINT *,"CONUS OR EUROPE? ('C' OR 'E') ---"
      READ 1010,WHERE
      IF(WHERE.EQ."C".OR.WHERE.EQ."E") GO TO 15
      PRINT *,"PLEASE ENTER 'C' FOR CONUS OR 'E' FOR EUROPE ---"
      GOTO 10
   15 PRINT *,"ENTER FORCE USAGE --- "
      READ *,FU
      IF(WHERE.EQ."E") GO TO 40
   20 DO 30 I=1,15
   30 PW(I)=PWC(I)
      GO TO 60
   40 DO 50 I=1,15
   50 PW(I)=PWE(I)
   60 P15=100
      IF(P15.EQ.100.)GOTO 70
      PRINT *,"WARNING THE MIX DID NOT TOTAL 100%"
   70 F15=P15/100.
      DO 80 I=1,12
   80 PV(I)=F15*PV1(I)
      IP15=P15
      DO 100 I=1,12
      DO 90 J=1,15
      ENOB(I,J)=OIR*FU*PV(I)*PW(J)
   90 CONTINUE
  100 CONTINUE
      B=0
      DO 120 I=1,12
      DO 110 J=1,15
      ENOB(I,J)=ENOB(I,J)*ACA(I,J)
      B=ENOB(I,J) +B
  110 CONTINUE
  120 CONTINUE
      PRINT 1080,B
 1010 FORMAT(A10)
 1020 FORMAT(1H1,
     1 10X,A10,I3,"  F-15 MIX (",A10,")",
     2 //,10X,"OIR =",F10.2," / 10**6   FU = ",F10.4," * 10**6",
     3 ////,25X,"EXPECTED NUMBER OF BIRDSTRIKE (UNCORRECTED)")
 1025 FORMAT(/,3X,"VELOCITY   ",25X,"BIRD WEIGHT (LBS)",
     1 /,3X,"(KNOTS)   ",15F8.3)
 1030 FORMAT(/,3X,A10,15F8.4)
 1040 FORMAT(////,25X,"EXPECTED NUMBER OF BIRDSTRIKES (CORRECTED)")
 1080 FORMAT(/,25X,"THE TOTAL EXPECTED NUMBER OF PENETRATIONS = ",F10.4)
      END
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REFERENCES

1. "An Analytical Methodology to Predict Potential Aircraft Losses Due to Canopy Birdstrikes," April 1980, Dr John C. Halpin and John M. Griffin, Aeronautical Systems Division, Wright-Patterson Air Force Base, Dayton, Ohio.

2. "Evaluation of the Birdstrike Threat to T-38 Transparencies," UDR-TM-79-12, July 1979, A. Berens, University of Dayton Research Institute, Dayton, Ohio.

3. "List of Identified Birds Involved in Bird Strikes," Logbook Call #204-293, May 1982 - March 1983, obtained from Lt Will, Bird Aircraft Strike Hazard Team, Tyndall AFB.

4. "List of Identified Birds Involved in Birdstrikes," March 1976 - September 1977, Obtained from Lt Will, Bird Aircraft Strike Hazard Team, Tyndall AFB.

5. "Weights of a Number of Birds," May 1970, G. Kaiser, Canadian Wildlife Service.

6. "F-15C/D Structural Loads Report for Production Eagle Package," MDC A5318, October 1978, McDonnell Aircraft Company.

7. "Final Report Windshield/Canopy Bird Impact Resistance," August 1977, McDonnell Aircraft Company.

8. "F-15 DRF Structural Design Criteria," Memorandum 199-DRF-169, September 1982, McDonnell Aircraft Company.

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